DECEMBER 2023

Centralville Sewer Separation Preliminary Design Report

(Humphrey's Brook PDR)

Volume 1

Prepared for:

Lowell Regional Wastewater Utility

DUCK ISLAND
LOWELL REGIONAL WASTEWATER UTILITY

CDM Smith

CENTRALVILLE SEWER SEPARATION PRELIMNARY DESIGN REPORT (HUMPHREYS BROOK PDR)

CERTIFICATION STATEMENT

I certify under penalty of perjury that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I have no personal knowledge that the information submitted is other than true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Aaron Fox
Executive Director
Lowell Regional Wastewater Utility

12/31/2023
Date

December 29, 2023

Mr. Aaron Fox
Lowell Regional Wastewater Utility
451 First Street Boulevard, Route 110
Lowell, Massachusetts 01850

Subject: Centralville Sewer Separation Preliminary Design Report
2023 Consent Decree (pending)

Dear Mr. Fox:

In accordance with the subject Consent Decree, CDM Smith is pleased to submit this Centralville Sewer Separation Preliminary Design Report (PDR) to the Lowell Regional Wastewater Utility (LRWWU), which addresses Paragraph 10 of the Consent Decree (CD) with respect to the preparation of the Humphrey's Brook/Billings Brook Preliminary Design Report.

The PDR summarizes the evaluation of the Centralville area to develop an engineering approach to separate the combined sewer system serving this neighborhood. Sewer separation of this area will reduce combined sewer overflow (CSO) discharges from LRWWU's collection system, which will comply with the requirements of the CD. The engineering work included an assessment of the system based on limited field investigations, extensive modeling to establish pipe conveyance requirements based on a range of design storms, and the development of 30 percent design drawings (in Volume 2 of this report) that were used to assess pipe route, potential utility conflicts, and construction challenges associated with the proposed separation plan.

As you are aware, sewer separation of the Humphrey's Brook/Billings Brook Drainage Area (2000 HB PDR Area) is particularly complex due to several factors unique to this drainage area, including:

- Topography that transitions sharply from steep slopes in the upper reaches of the basin to flat grades in the lower reaches of the basin, creating the need for large conduits in the lower reaches of the area to convey flow to the river with little slope,
- The 96-inch diameter North Bank Interceptor, which runs along the bank of the Merrimack River, severely limiting access for a large new drainage pipe to the river,
- The earthen levee, constructed for flood protection purposes, and VFW Highway (MADOT roadway on top of the levee) along the bank of the Merrimack River, creating construction and permitting complications for any new pipeline to the river,
- The West Pump Station, which was constructed for flood protection purposes, and the need to maintain the primary functionality of this station (flood protection) under any recommended sewer separation plan,

- The variability of water levels in the Merrimack River, as high-water levels can create a hydraulic constraint for the discharge of a new drainage pipe to the river.

To address the complication of a gravity stormwater discharge into the Merrimack River during river flood conditions, the concept of connecting the drain to the West Pump Station was investigated as part of this PDR and found to be impractical for several reasons, including:

- The challenges of the physical connection of large drain conduit to the outfall chamber at the West Pump Station considering the physical conflict of the 96-inch North Bank Interceptor that goes around the station, and
- The complications of using the West Pump Station and CSO Diversion Structure for both CSO and drainage purposes, and the potential for interference with the primary function of these structures (flood protection).

For these reasons, the PDR developed two alternatives that instead convey most of the flow from a new drainage system to new dedicated drainage outfalls, with only a small portion of flow from the new drainage system conveyed to the West Pump Station/Outfall. These alternatives provide several benefits in terms of routing for the new large drain piping to mitigate construction challenges, utility conflicts, and costs. Additionally, one of these alternatives could potentially facilitate the future sewer separation of portions of Sewer Area 40, located adjacent to the Humphrey's Brook Drainage Area in the Centralville area, thereby potentially provide greater overall CSO reduction benefit.

The two alternatives are presented in the PDR but a final decision regarding the selected alternative is pending given the many unique aspects of this project. Over the next several months, engineering activities will continue to advance the design and allow for final selection of a discharge alternative. Section 8 of the PDR describes these activities. This schedule also provides an opportunity to obtain feedback from the regulatory agencies over the next several months so that their comments can be incorporated into the decision regarding a selected alternative.

We believe that this PDR is an important step in implementing a cost-effective, technically sound approach to sewer separation in the 2000 HB PDR Area and in the City as a whole, and we look forward to the opportunity to discuss the content of this PDR with you soon.

Sincerely,

Michael J. Walsh, P.E.
Senior Vice President
CDM Smith Inc.

cc: Evan Walsh, Lowell Regional Wastewater Utility

Contents

Figures

Tables

Appendices (Volume 2)

Acronyms and Abbreviations

ACP	Asbestos Cement Pipe
ADR	Automated Defect Recognition
AI	Artificial Intelligence
AO	Administrative Orders
ARI	Average Recurrence Intervals
AUL	Activity and Use Limitations
BVW	Bordering Vegetated Wetland
CB	Catch Basin
CCTV	Closed-Circuit Television
cfs	Cubic Feet per Second
CIPP	Cured-in-Place-Pipe Lining
City	City of Lowell, Massachusetts
CMP	Corrugated Metal Pipe
CSO	Combined Sewer Overflow
CSS	Combined Sewer System
CWA	Clean Water Act
DCR	Department of Recreation and Conservation
Duck Island	Duck Island Wastewater Treatment Facility
DPW	Department of Public Works
EEA	Executive Office of Energy and Environmental Affairs
ENF	Environmental Notification Form
FDR	Flood Damaged Reduction System
fps	Feet per Second
GMPS	Inland Water/Green Mountain Pipeline Services
gpd/in-mile	Gallons per Day per Inch-Mile
GPM	Gallons per Minute
GPS	Global Positioning Satellite
HGL	Hydraulic Gradeline

I/I	Infiltration /Inflow
ICP	Integrated Capital Plan
LCD	Lowell City Datum
LoF	Likelihood of Failure
LRWWU	Lowell Regional Wastewater Utility
LSP	Licensed Site Professional
LTCP	Long-Term Control Plan
LUW	Land Under Water
MACP	Manhole Assessment Certification Program
MassDEP	Massachusetts Department of Environmental Protection
MassDOT	Massachusetts Department of Transportation
MassGIS	Bureau of Geographic Information
MCP	Massachusetts Contingency Plan
MEPA	Massachusetts Environmental Protection Act
mgd	Million Gallons per Day
MHC	Massachusetts Historical Commission
MHD	Massachusetts Highway Department
MS4	Municipal Separate Storm Sewer System
MTBM	Micro Tunnel Boring Machine
NASSCO	National Association of Sewer Service Companies
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NOAA	National Oceanographic and Atmospheric Administration
NOI	Notice of Intent
NPC	Notice of Project Change
O&M	Operations and Maintenance
OB	Observation Well
OOC	Order of Conditions
OSHA	Occupational Safety and Health Administration
PACP	Pipeline Assessment Certification Program

PDR	Preliminary Design Report
PID	Photoionization Detector
PM	Particulate Matter
PVC	Poly Vinyl Chloride
RAO	Response Action Outcome Statement
RCP	Reinforced Concrete Pipe
RDA	Request for Determination of Applicability
RTN	Regional Tracking Numbers
SRF	State Revolving Loan Fund
SV	Self-Verified
SWMM	Stormwater Management Model
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
Utility	Lowell Regional Wastewater Utility
VCP	Vitrified Clay Pipe
WWTF	Wastewater Treatment Facility

1.0 Introduction

1.1 Background

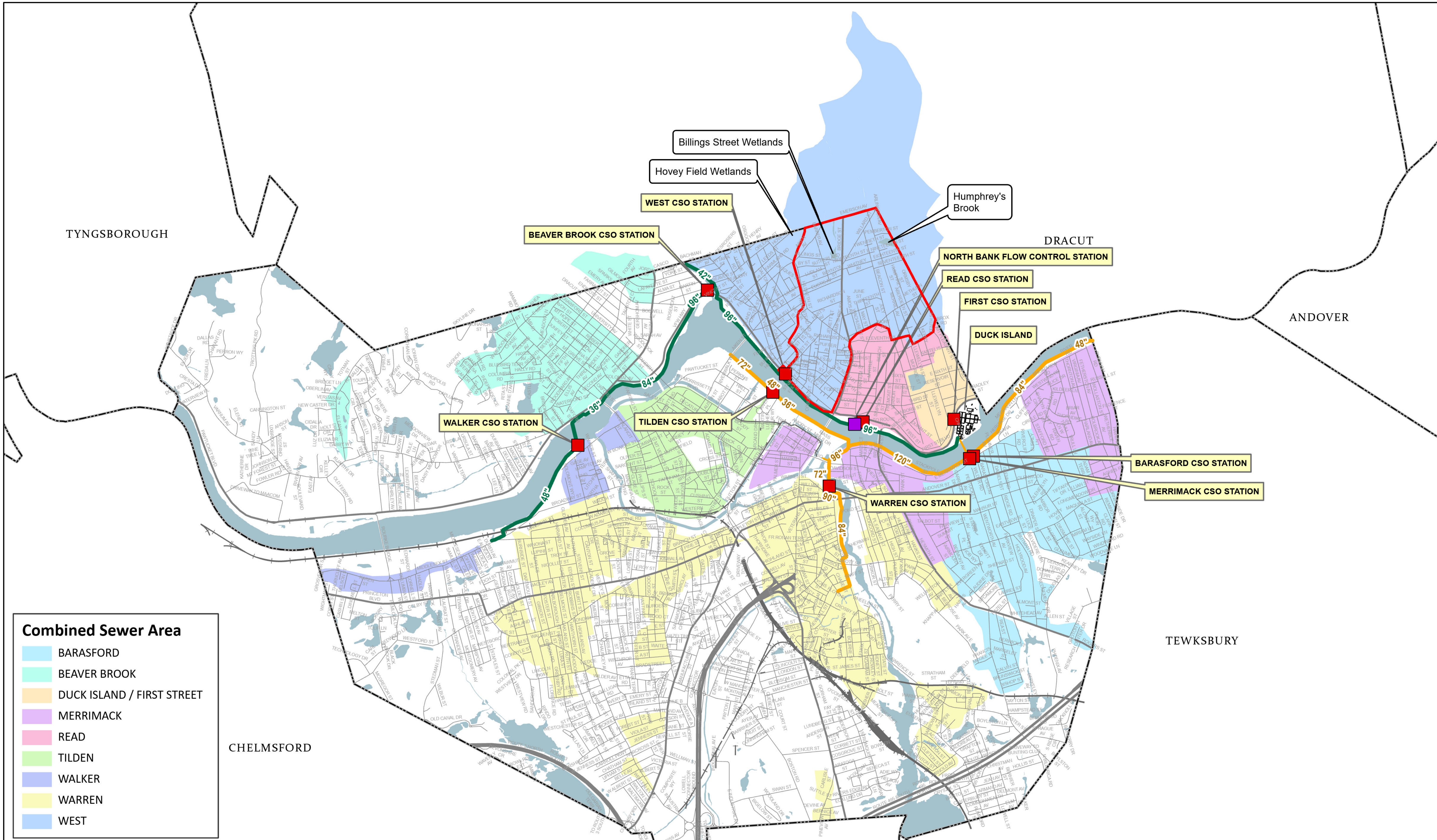
The City of Lowell, Massachusetts (City) has a combined sewer system (CSS) like many older cities in the northeast United States. The CSS was originally designed to convey both sanitary wastewater (residential, commercial, and industrial flow) and stormwater flow within a single pipe in the street. During wet weather, stormwater entering the CSS (via catch basins, surface inflow, and private connections) can exceed the hydraulic capacity of the combined sewer and interceptor piping system, resulting in the discharge of untreated combined sewer overflow (CSO) to receiving waters. The Lowell Regional Wastewater Utility (LRWWU or Utility) operates the Duck Island Wastewater Treatment Facility (Duck Island) and sewer and drainage collection system facilities in the City.

LRWWU has nine permitted outfalls where untreated CSOs discharge from the combined sewer system during rain storms. The CSOs discharge to Beaver Brook (Beaver Brook Station #007-SDS#2), the Concord River (Warren Station #020-SDS#6), and the Merrimack River (Walker Station #002-SDS#1, West Station #008-SDS#3, Read Station #011-SDS#4, First Station #012-SDS#5, Tilden Station #027-SDS#7, Barasford Station #030(1)-DSD#8-1, Merrimack Station #030(2)). **Figure 1.1** shows Lowell's combined sewer and sanitary sewer systems.

This Centralville Sewer Separation Preliminary Design Report (Centralville PDR) focuses on a portion of the tributary basin contributing combined sewer flow to the West Station, which includes the CSO Diversion Structure, West Station Outfall and the West Pump Station (#008-SDS#3). Dry weather flow and portions of wet weather flow received at this station are conveyed to Duck Island via a direct connection to the North Bank Interceptor System; excess wet weather flow is diverted at the CSO Diversion Structure away from the North Bank Interceptor System into the West Station Outfall as either gravity discharge or into the West Pump Station, as a pumped discharge via the West Station Outfall, during significant rain events.

The West Station is an integral part of the City of Lowell's Flood Damage Reduction Project (FDR Project), installed in the late 1930s by the U.S. Army Corps of Engineers (USACE), to protect low lying areas of the City from Merrimack River Floodwaters. The pump station operates, in unison with a system of earthen levees and concrete I-walls, to pump out wet weather sewer flow into the Merrimack River during periods of high river conditions to avoid property flooding.

The tributary combined sewer basin addressed in this report is referred to as the Centralville CSS, which includes the Humphrey's Brook Area (as identified in the 2000 Humphrey's Brook Area Combined Sewer Separation Project Preliminary Design Report, discussed in Section 1.2, and referenced hereinafter as the 2000 HB PDR) and Sewer Area 40. Humphrey's Brook is an unnamed surface water system with overland drainage running through the Town of Dracut into Lowell's CSS at Humphreys Street in Lowell (at the Dracut border). The moniker for the brook was generated based on the prior evaluation report where CSO planning efforts focused on eliminating Humphrey's Brook flow from the sewer system to reduce CSO discharges using a new separate main drain conduit with a new discharge to the Merrimack River.



Lowell, Massachusetts
Centralville Sewer Separation PDR

Figure 1.1
Existing Combined Sewer System

During prior system assessments, two additional surface drainage inflow sources (from Dracut) were also identified and added to the list for possible removal from the sewer system - the Billings Street Wetlands at Billing Street and a stream from Dracut that enters the Lowell CSS near Hovey Field (Hovey Field Wetlands). These CSS inflow locations are shown on Figure 1.1, along with the boundaries of the Dracut tributary drainage area, which encompasses approximately 450 acres outside the City limits.

1.2 Project History

The Humphrey's Brook area separation project has a long history.

Under the Clean Water Act (CWA) of 1986, municipalities nationwide must take steps to reduce or eliminate CSO discharges to receiving streams to improve water quality. In response, the United States Environmental Protection Agency (USEPA) issued a series of interim CSO control policies and adopted a final National CSO Control Policy in 1994. This Policy established a comprehensive national strategy to ensure that municipalities, permitting authorities, water quality standards authorities, and the public engage in a coordinated planning effort to develop and implement cost-effective CSO controls that meet appropriate environmental and health objectives. The Massachusetts Department of Environmental Protection (MassDEP) established its own CSO Policy (1997) reflecting the minimum requirements of the USEPA CSO Policy and compliance/maintenance of State Water Quality Standards.

To address the federal and state CSO regulations and policies, communities with combined sewer systems must submit a Long-Term Control Plan (LTCP) that identifies a program to abate CSO discharges.

In 1988, the USEPA alleged that the City was discharging pollutants into waters of the United States from CSO outfalls and certain unauthorized discharge points in its wastewater collection system in violation of the National Pollutant Discharge Elimination System (NPDES) permit and Section 301 (a) of the CWA. Accordingly, the United States, the Commonwealth of Massachusetts, and the City entered into a Consent Decree (Civil Action No. 87-0688) that required the City to take specific actions to address its NPDES permit.

To address the NPDES mandate, the Utility developed several CSO planning document updates, since the original 1988 Consent Decree, including:

- 1990 CSO Facilities Plan,
- (1998) 2002 Revised Draft Long-Term CSO Control Plan,
- 2014 CSO Phase 2 Long Term Control Plan, and
- 2019 Integrated Capital Plan.

Each of these planning documents was developed to address changing federal and state CSO control regulations, policies, and provide updated planning approaches; update the existing Stormwater Management Model (SWMM) hydraulic model of the CSS for system evaluation; identify and quantify progress on implementation of past CSO abatement measures; assess the benefits achieved by these implemented measures; and to update and revise the LTCP to reflect new costs and strategies to continue CSO control in Lowell. Each report included a phased set of recommendations to control CSO discharges from the City's CSS.

The USEPA issued Administrative Orders (AOs) at the conclusion of each of the LTCPs, and several in the interim periods, to facilitate additional planning and capital improvements to reduce uncontrolled CSO discharges from Lowell's CSS. Capital improvements included Duck Island improvements to maximize and provide reliable treatment of wet weather flows reaching Duck Island, sewer separation of key areas of the system including the Warren CSO Basin, implementation of real-time instrumentation and control to facilitate the use of in-line interceptor pipeline storage (including the construction of the North Bank Flow Control Station), and a sewer system rehabilitation program.

The potential to separate the Humphrey's Brook Basin was initially considered in the 1990 CSO Facilities Plan but it was not determined to be a high priority. As part of the development of the 2002 Revised Draft LTCP, CDM Smith (formerly CDM) completed a report entitled Conceptual Sewer Separation Plan for Selected Areas (June 1998). This report presented an initial evaluation of the City's CSS to identify drainage areas where the existing collection system could be readily separated (due to the proximity of nearby drainage channels) or where sewer separation could eliminate significant inflow sources such as streams and brooks entering the CSS. Based on the analyses, CDM Smith (formerly CDM) selected seven (7) key drainage areas and developed conceptual sewer separation plans, showing the potential routes of a new drainage piping system for each drainage area. These 7 drainage areas were also subject to excessive street flooding where sewer separation could reduce the street flooding potential and reduce CSO discharges.

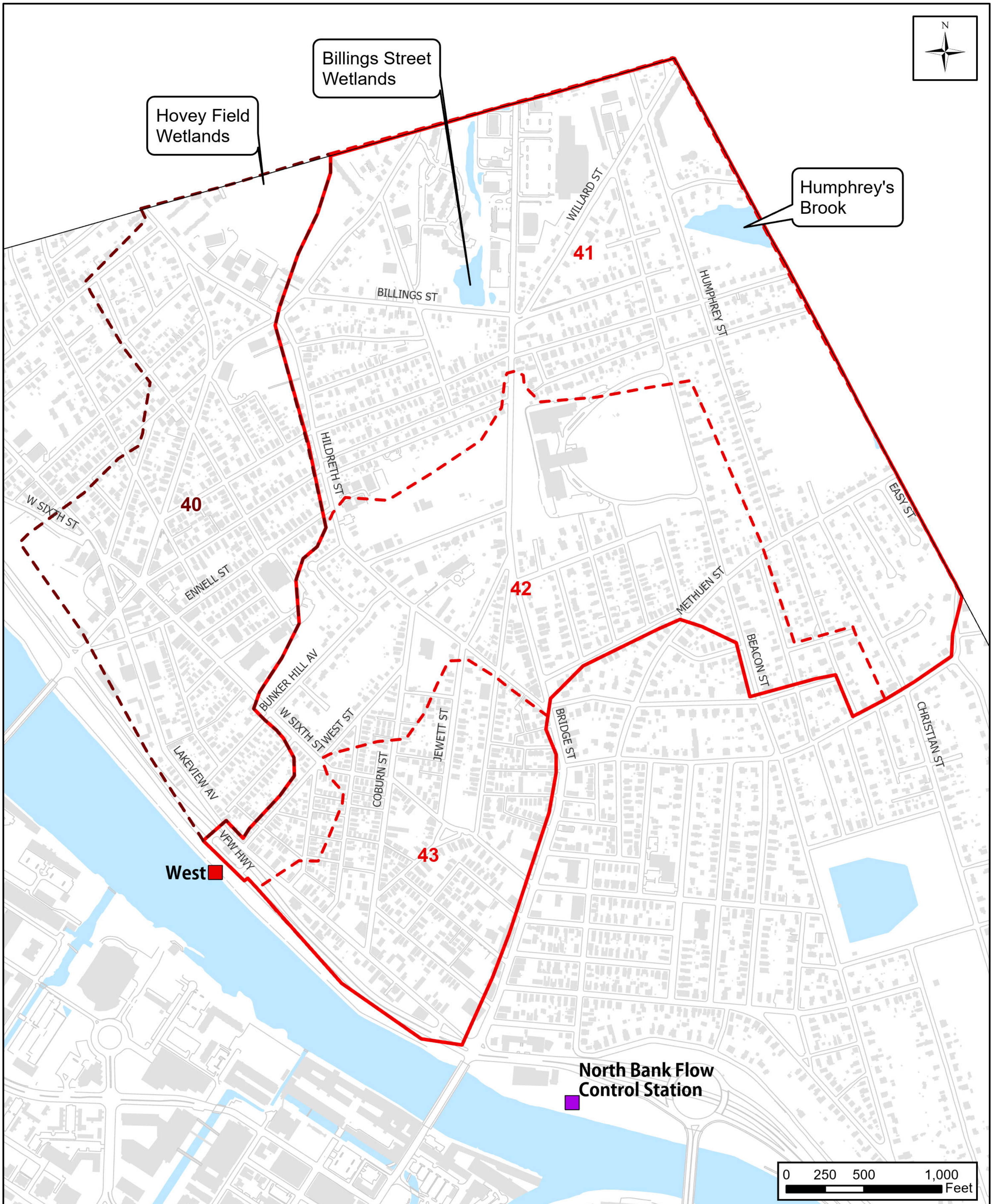
Based on the 1998 Conceptual Sewer Separation Plan for Selected Areas, the City engaged CDM Smith (formerly CDM) to complete the 2000 HB PDR, which focused on separation of Sewer Areas 41, 42, and 43 as shown in **Figure 1.2**. Initial costs and construction challenges were identified for the sewer separation of the basin in this report and a comparison was made to other CSO control strategies in the 2002 Revised Draft LTCP. Based on this assessment, and negotiations with USEPA and MassDEP, the City received an AO (Docket 03-22) from the USEPA that required implementation of a different set of system improvements as CSO control priorities in a compliance schedule including:

- Modifications to Duck Island to improve wet weather treatment capacity;
- Modifications to four CSO diversion stations (Read, Tilden, Merrimack, and Warren) to increase the use of in-line interceptor storage and reduce CSO discharges; and
- Completion of the Warren Street CSO Drainage Basin Sewer Separation Preliminary Design and implementation of its recommendations.

Accordingly, potential separation of the Humphrey's Brook Basin was delayed.

The 2014 CSO Phase 2 Long Term Control Plan presented a CSO control program and implementation schedule that did not include separation of the Humphrey's Brook Basin. MassDEP and USEPA did not approve this plan but allowed the City to continue with other system improvements to control CSO discharge and required the submittal of an updated plan to meet regulatory requirements.

In December 2019, the City submitted an Integrated Capital Plan (ICP), which included the City's proposed comprehensive plan for wastewater, drinking water, and stormwater capital and operational improvements. EPA and MassDEP provided comments to and requested additional information from the



Legend

Diversion Station and CSO Outfall

North Bank Flow Control Station

Sewer Area

40

41, 42, 43

2000 HB PDR Area

Lowell, Massachusetts

Centralville Sewer Separation PDR

Figure 1.2

Centralville Sewer Separation PDR Area

City on the proposed ICP and the CSO control strategy. Negotiations continued with the agencies to submit the required information, but these efforts reached a stalemate.

In June 2022, the regulatory agencies, along with the U.S. Department of Justice and the Commonwealth of Massachusetts Department of Justice, began negotiations to develop a new Consent Decree with violation findings (NPDES permit, Section 301(a) of the Clean Water Act, and provisions of the 2003 Small MS4 General Permit) and remedial measures to address these violations. Negotiations continued through 2022 and 2023. The 2023 Consent Decree is now finalized and will be submitted to Federal Court for approval in 2024.

Based on this 2023 Draft Consent Decree, under Section VI. Remedial Measure (Paragraph 10), the City must:

> *On or before December 31, 2023, the City shall submit to EPA and MassDEP for review and approval a Preliminary Design Report and Sewer Separation Implementation Schedule for the Humphrey's Brook/Billings Brook drainage area ("Humphrey's Brook PDR)." The Humphrey's Brook PDR shall detail the engineering approach to: carry out sewer separation in these areas; address infiltration and inflow into the collection system in these areas, including private sources; prioritize sewer separation based on CSO control benefits, cost, and construction challenges with the goal of sequencing the work to achieve the greatest CSO reduction benefits; and identify major technical and permitting issues. The Humphrey's Brook PDR shall include cost estimates for the recommended work, and shall specifically incorporate the following provisions:*
>
> a. *Conceptual design plans which will result in the separation of the sewer and storm drain system throughout the Humphrey's Brook/Billing's Brook drainage area;*
>
> b. *Phasing of the sewer separation work to achieve:*
>
>   i. *Removal of Humphrey's Brook flows from the City's combined sewer system, including surface flows from the Town of Dracut, by December 31, 2027; and*
>
>   ii. *Separation of the sewer and storm drain system in the Humphrey's Brook/Billing's Brook drainage area by December 31, 2031.*
>
> c. *Engineering design plans for each phase of the work shall be approved by MassDEP prior to commencing construction.*

It is important to note that the project has been a priority for the City for many years but due to the significant cost and construction challenges, separation of the Humphrey's Brook Basin has been deferred while more cost-effective CSO control and sewer separation projects were implemented. During Consent Decree negotiations, separation of the Humphrey's Brook Basin CSS was adopted as one of the renewed priorities based on system surcharging and street flooding in several areas of the basin. This is a similar approach that the City has undertaken in its previous sewer separation projects, i.e., to provide property owners with a solution to reduce the impact of excessive rainstorms in the City.

1.3 Purpose

The purpose of this report is to provide an updated preliminary design of the proposed sewer separation of the existing combined sewer collection system in the 2000 HB PDR area, consisting of Sewer Areas 41, 42, and 43 as shown in Figure 1.2, to meet the requirements of the draft 2023 Consent Decree.

This report includes the development of preliminary design plans and profiles of all proposed new drain piping to fully assess pipe connectivity, potential underground utility conflicts, outfall locations, update implementation/construction costs, and to further consider permitting and construction challenges (based on past City sewer separation projects).

System operations have changed since the initial 2000 HB PDR including the re-activation of the West Pump Station and the recognition of the adjacent earthen levee system along the Merrimack River as an important function of the City's FDR Project. In addition, this report is intended to utilize new system flow metering (obtained in 2023 as part of the concurrent Infiltration/Inflow (I/I) Analysis Plan) to update the SWMM model for analysis of CSO benefits achieved by separation of the combined sewer area tributary to the West Station and CSO Outfall. The report includes the identification of the Phase 1 and Phase 2 Humphrey's Brook project components to meet Consent Decree Paragraphs 10.b.i and 10.b.ii, presented above.

1.4 Study Area

Figure 1.2 shows the 2000 HB PDR area boundaries, which are tributary to the West Station. Humphrey's Brook and the Billings Street Wetland inflow sources connect through Sewer Area 41 on the upstream side of the basin. In addition, Figure 1-2 shows Sewer Area 40, which is adjacent to the 2000 HB PDR area, but also contributes combined sewer flow to the North Bank Interceptor System at the West Station. Another Dracut inflow source, Hovey Field Wetlands, enters the sewer system in Sewer Area 40.

The study focuses on a majority of the Centralville neighborhood of the City north of the Merrimack River. Approximately 400 acres of the Humphrey's Brook Basin area are located within the city limits.

Centralville is characterized by steep hills in the north and east portions of the basin, which descend into the flatter catchment area just north of the VFW Highway. Land use is primarily one- and two-family homes and small multifamily properties in the mid- to north portions of the neighborhood, while more densely developed areas with multi-story apartment buildings and small commercial businesses are located in the southern portion of the basin.

1.5 Approach

The preliminary design is intended to identify the most feasible and cost-effective alternative for new piping systems to remove the Humphrey's Brook, Billings Street Wetlands, and Hovey Field Wetlands inflow from the CSS and provide for eventual sewer separation of the adjoining collection system in the drainage area. This report summarizes the extensive field investigations, preliminary design drawing development, hydraulic evaluation, and alternatives analyses conducted to complete and enhance the preliminary design for sewer separation of this area.

Preliminary engineering for the project consisted of the following activities:

- Collection of available information, mapping, and reports related to the ongoing assessment and conceptual design of the separation work for the Humphrey's Brook Basin;
- Completion of field investigations to evaluate potential pipeline routes, existing utilities, actual site conditions, public inflow sources, construction issues, etc.;
- Assessment of the existing sewer system conditions and development of recommendations to rehabilitate the system, as necessary, using existing information, client discussions, CCTV inspection, manhole inspections, smoke testing, etc.;
- Consideration of the potential reuse of existing combined sewer pipes to convey wastewater or stormwater as an alternative to larger drain pipes;
- Development and use of a hydraulic SWMM of a new drain system and the surface input of the Humphrey's Brook/Billings Street Wetlands/Hovey Field Wetlands area, using flow data, to develop a drain pipe network optimized for hydraulic conditions and pipe slopes;
- Re-development and calibration of the existing combined sewer SWMM model to provide simulations of CSO benefits that may be achieve by the phased separation program;
- Identification of permitting issues and environmental impacts along the proposed routes;
- Completion of initial subsurface investigations to identify potential bearing soil and environmental issues, if any, along with bedrock depths;
- Field survey to support the evaluation of alternatives and development of design drawings;
- Evaluation of pipe route alternatives to minimize project costs and surface disturbances during construction;
- Preparation of plan and profile drawings to identify critical elevation conflicts with existing underground utilities;
- Estimation of most probable construction and projects costs for the recommended alternative plans;
- Development of a comprehensive preliminary design report to summarize the findings and provide recommendations along with an implementation schedule; and
- Development of a preliminary design report to summarize the findings.

2.0 Existing System

2.1 General

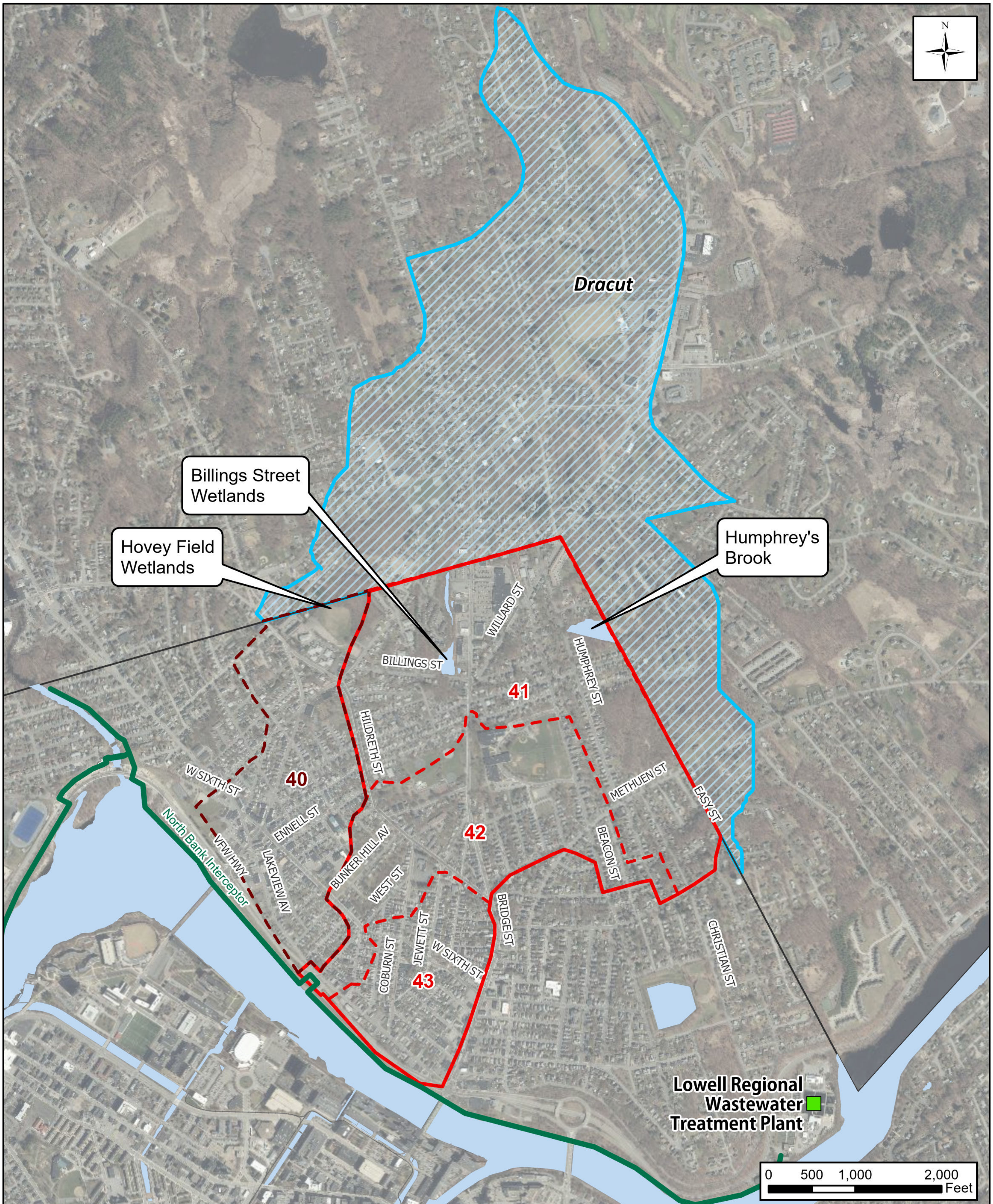
An understanding of the existing CSS is important to develop and evaluate piping alternatives that will effectively separate the 2000 HB PDR Area and Sewer Area 40. This requires an assessment of the condition of the existing pipe network, including a review of structural pipe integrity, reliability, and operation of the collection system, and a review of available records and anecdotal information regarding system problems (such as sewer back-ups, street flooding, etc.).

An analysis of the existing pipe network is also necessary to identify current conveyance capacity. The level of service provided by the existing combined system (i.e., the capacity to convey a certain sized storm event) should be maintained or improved through the installation of new pipes to separate the existing system. This is considered in Section 4 Hydraulic Modeling of the Drainage System and Section 6 Development of Alternatives.

Figure 2.1 shows the original 2000 HB PDR Area, which includes Sewer Areas 41, 42, and 43, and the adjacent Sewer Area 40, which also is tributary to the West Station. The 2000 HB PDR Area is comprised of a combined sewer system that collects stormwater and wastewater flow from nearly 400 acres in Lowell and conveys it by gravity to the 96-inch diameter North Bank Interceptor that runs along the Merrimack River. Sewer Subarea 40 conveys flow from a combined sewer system with just over 100 acres tributary to West Station.

Figure 2.1 also shows the Dracut surface water tributary area that is also conveyed into LRWWU's collection system at three locations - Humphrey's Brook at Humphrey Street, the Billings Street Wetlands at Billings Street, and Hovey Field Wetlands that enter Lowell at Hovey Field near Hildreth Street. The Dracut tributary area is served by a sanitary sewer system that enters Lowell's sewer system at many points at the boundary between the two communities. More importantly, Dracut has separated drainage systems that also contribute runoff to the LRWWU sewer system at three key inflow points. The Dracut surface flow covers about 450 acres. However, it is important to note that the surface water in Dracut is composed of a series of wetlands and hydrologic flow conditions that dampen peak flow. As a result, the net runoff generated by the Dracut portion of the area tributary to the Lowell system is much smaller per acre than the runoff generated by the City's combined sewer system.

Figure 1.1 showed the interceptor system, which conveys flow from west to east along both banks of the Merrimack River to the Duck Island Wastewater Treatment Facility, located on the north bank side of the Merrimack River. The plant has a design capacity of 32 mgd for dry-weather flow and a wet-weather treatment capacity of up to 112 mgd, with a bypass of the secondary aeration/biological treatment process. All flows are chlorinated before discharge.



Legend

Lowell Regional Wastewater Treatment Plant

North Bank Interceptor

Dracut Surface Water Tributary Area

Sewer Area

40

41, 42, 43

2000 HB PDR Area

Lowell, Massachusetts

Centralville Sewer Separation PDR

Figure 2.1

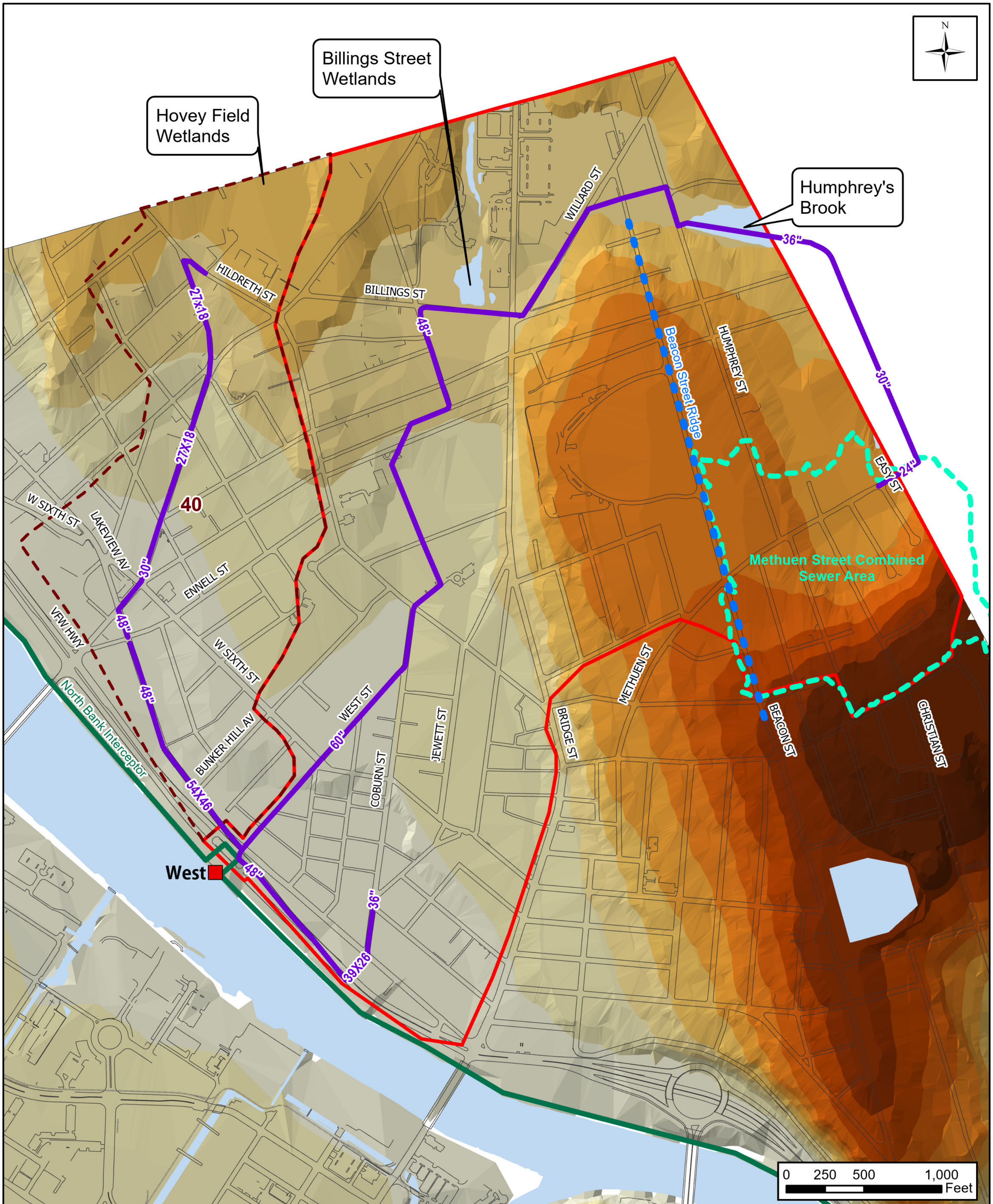
Centralville Project Area

2.2 Topography

Figure 2.2 shows the existing topography and key features of the 2000 HB PDR Area. The terrain includes steep hills in the north and east with the ridge running along Beacon Street. This ridge serves as a divide of the Methuen Street area, a portion of which flows east towards Dracut; the remainder of the street and study area flows to the west. The Methuen Street area combined sewer flow follows a circuitous path flow east into Dracut, then north up to Humphrey's Brook, where it enters the sewer collection system at Humphrey Street and drains southwest.

The main drain conduit, shown in purple in Figure 2.2, predominantly follows along the old streambed from Humphrey's Brook to the Merrimack River. The high elevations along the Beacon Street ridge rapidly descend north and west toward the main collector line as sewer flow is conveyed by gravity (following topography) downstream into the western and southern regions of the system. Generally, the western and southern regions approaching the Merrimack River are much flatter. Flow from the main collector continues southwest through this flat, lower elevation area, toward West Street/VFW Highway and then the North Bank Interceptor at the West CSO Diversion Structure. VFW Highway (constructed in the 1960s) is located on an earthen levee system originally constructed by the US Army Corps of Engineers in the 1940s.

These topographical features are a significant factor in the design of new gravity wastewater or stormwater collection systems in Lowell as the new pipes should follow this topography to avoid deep and expensive excavations. Pipes in the upper portion of the study area with steep terrain can have steeper pipe slopes, which can decrease new pipe sizes in these areas. In the lower parts of the basin near the river, the pipe slopes are flatter to match terrain to minimize pipe burial depth and to eventually connect the drain outlet to the river above the river bottom. Flatter pipe slopes increase the pipe sizes for the same conveyance capacity.



Legend

Elevation (ft)
Max: 300
Min: 61

Diversion Station and CSO Outfall

Main Drain Conduit

North Bank Interceptor

Methuen Street Combined Sewer Area

Sewer Area 40

2000 HB PDR Area

CDM Smith

DUCK ISLAND LOWELL REGIONAL WASTEWATER UTILITY

Lowell, Massachusetts
Centralville Sewer Separation PDR

Figure 2.2
Topography and Existing System

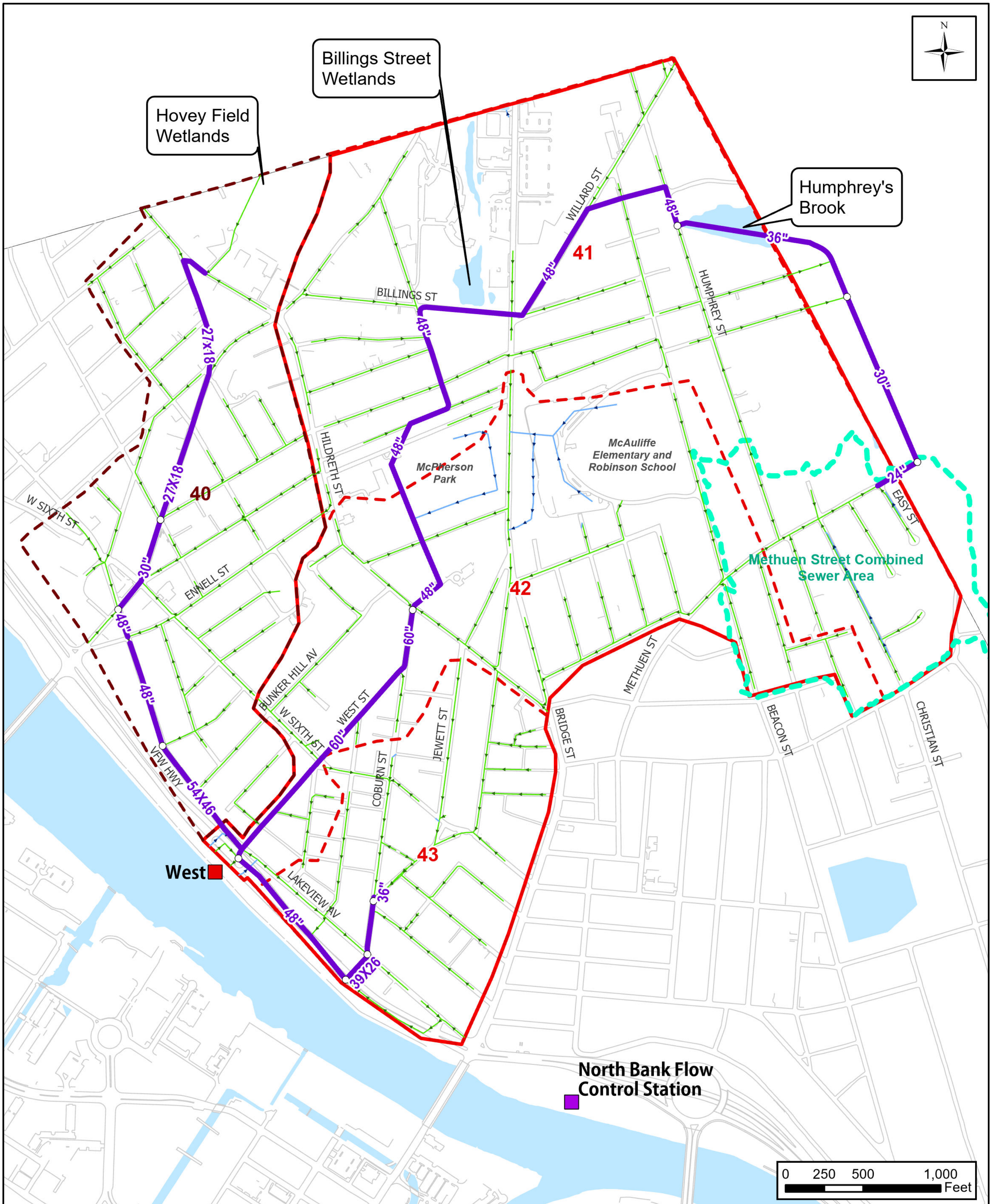
2.3 Combined Sewer System

2.3.1 Overview

Figure 2.3 shows the existing CSS in the 2000 HB PDR Area and Sewer Area 40. Based on the Utility's GIS records, the existing combined sewer system in the 2000 HB PDR Area is comprised of approximately 60,000 linear feet of sewer pipe ranging in size from 8-inch to 60-inch diameter pipe and non-circular brick pipe. Sewer Area 40 contains an additional 22,000 linear feet of sewer pipe. This sewer collection system conveys sanitary sewage, surface runoff collected by the City's catch basins, and other sources of public and private infiltration and inflow (I/I) to the North Bank Interceptor. Infiltration, typically from groundwater, enters the system through the aging City sewers and potentially through private property sewer laterals. Private inflow enters the City's sewer via catch basins or yard drains, roof drain/downspout connections, or basement drains or open sewer cleanouts.

There are three major surface water sources, primarily from Dracut, that discharge to the CSS: Humphrey's Brook, Billings Street Wetlands and Hovey Field Wetlands. There is a short segment of drain on Easy Street that has a separate outfall pipe. There are also three areas with stormwater drain systems that recombine to the sewer system - Christian Street, McPherson Park, and Robinson Middle School/McAuliffe Elementary School.

There are nearly 300 LRWWU catch basins in the 2000 HB PDR Area and approximately 80 catch basins in Sewer Area 40 that collect surface water runoff from City streets.



Legend

- Diversion Station and CSO Outfall
- North Bank Flow Control Station
- Pipe Diameter Change
- Main Drain Conduit
- Sewer Gravity Main
- Existing Drain
- Methuen Street Combined Sewer Area

Sewer Area
- 40
- 41, 42, 43
- 2000 HB PDR Area

CDM Smith

DUCK ISLAND LOWELL REGIONAL WASTEWATER UTILITY

Lowell, Massachusetts
Centralville Sewer Separation PDR

Figure 2.3
Combined Sewer System

2.3.2 Main Conduit

As shown in Figure 2.3, the existing combined sewer in the 2000 HB PDR Area and Sewer Area 40 is served by a main collector sewer that begins at the inlet for Humphrey's Brook (on Humphrey Street) and flows downstream to the West Station.

Figure 2.4 Humphrey's Brook

The Humphrey's Brook inlet structure is composed of a stone headwall as shown on **Figure 2.4**. The inlet structure directs Humphrey's Brook through a short segment of 36-inch pipe into a manhole on the 48-inch combined sewer in Humphrey Street. That Humphrey Street 48-inch brick sewer also collects wastewater flow from the 36-inch sewer originating from the Methuen Street Area. The 48-inch combined sewer runs north along Humphrey Street before cutting cross-country to the west to connect with Willard Street. The 48-inch line then runs southwest down Willard Street, crosses Bridge Street, and enters Billings Street.

Figure 2.5 Billings Street Wetlands

The Billings Street Wetlands flows into the sewer through a concrete inlet control structure located on the north side of Billings Street. Flow enters the structure via openings on each side and a grate on top and is connected to the existing 48-inch brick sewer. **Figure 2.5** shows the Billings Street Wetlands and inlet structure. The main conduit continues along several streets and a cross-country segment through McPherson Park before eventually connecting with a 60-inch combined sewer line at the intersection of Coburn Street and Hildreth Street. The 60-inch brick conduit then continues down Coburn and West Street, where it connects to the 96-inch North Bank Interceptor at the West Street CSO Diversion Structure.

Sewer Area 43 flows are conveyed by a second larger collector pipe beginning at the intersection of Coburn Street and Jewett Street as a 36-inch pipe that immediately transitions to a 39-inch by 26-inch brick sewer. The alignment continues south along Coburn Street where it then crosses Lakeview Avenue and travels cross country to the VFW highway where it connects to the West Station.

Figure 2.3 also shows the Methuen Street combined sewer area. As mentioned above, this area drains to the northeast because of its topography into Dracut. This local combined sewer system collects flow from nine streets in the eastern section of the project area. The flow then travels further east on Methuen Street into Dracut where it turns north and runs cross country before discharging into the Humphrey's Brook sewer adjacent to the Humphrey's Brook inlet point.

Area 40 flows are conveyed to the West Station beginning on Hildreth Street at the northern end of this basin. Surface flow from the Hovey Field Wetlands enters a pipe that proceeds under Hovey Field and connects to the sewer on Hildreth Street. **Figure 2.6** shows the Hovey Field inlet for Dracut flow. The Hovey Field inlet is a 24-inch diameter connection pipe to the 27-inch by 18-inch brick sewer on Hildreth Street just east of Essex Street. The collector combined sewer follows Hildreth Street north for a short segment, runs south on Essex Street to Aiken Avenue, and then follows Lakeview Avenue where it combines with the 60-inch West Street pipe and connects to the West CSO Diversion Structure. The brick sewer increases along this run up to a 54-inch by 46-inch brick sewer.

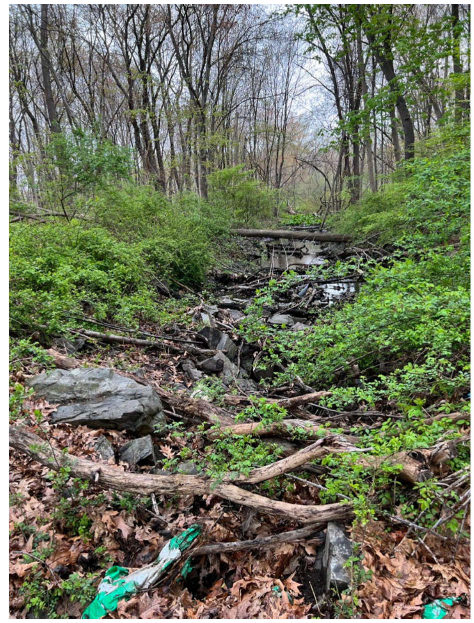


Figure 2.6 Hovey Field

The remaining 2000 HB PDR Area is comprised of 8-inch to 36-inch collector sewers that extend out from the mainline conduits described above.

2.3.3 System Characterization

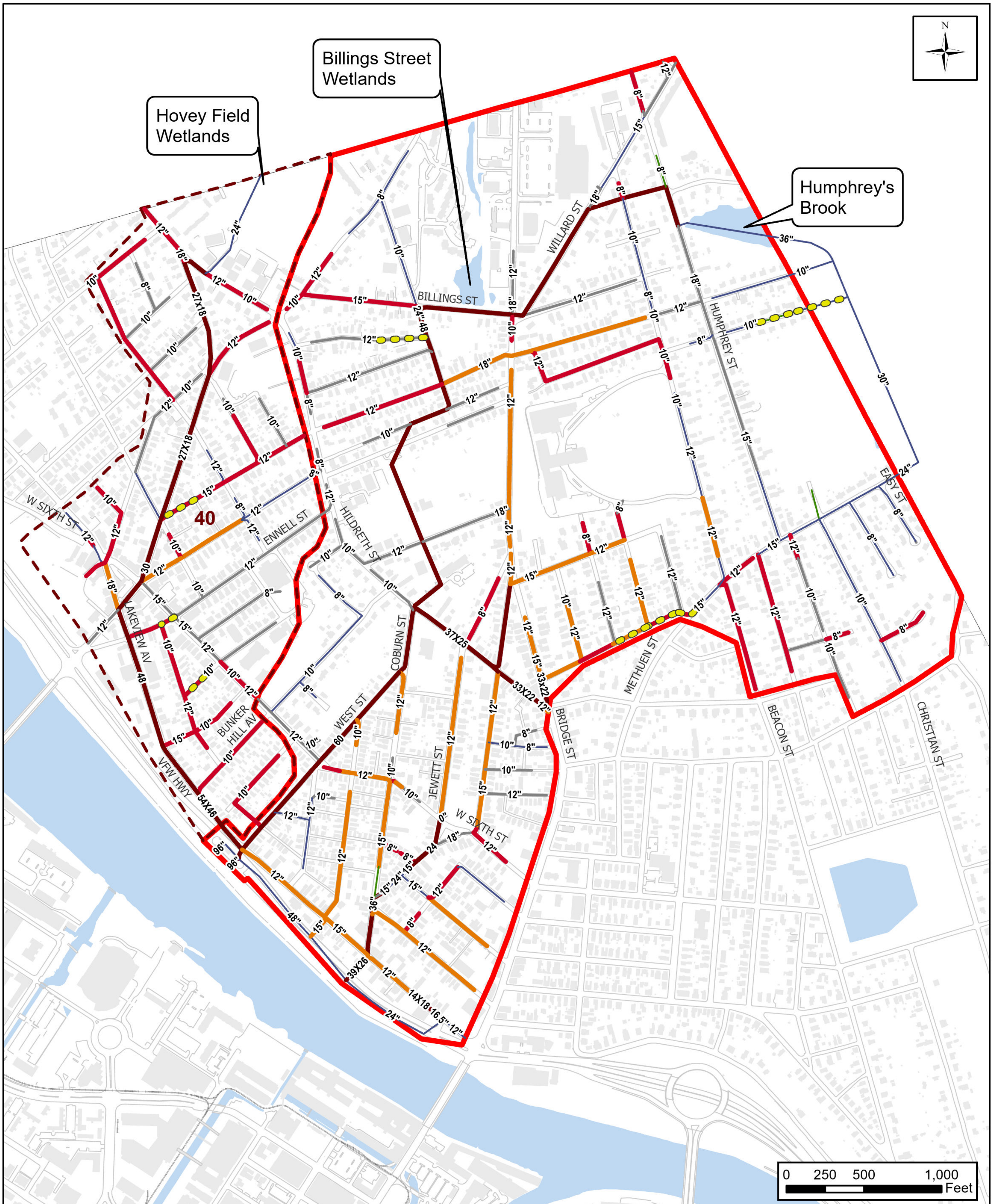
Table 2.1 provides a summary of the pipe material breakdown for the 2000 HB PDR Area and Sewer Area 40. Pipe materials include vitrified clay pipe (VCP), cast iron, concrete, and brick. About 20 to 22 percent of the pipes in these two systems is comprised of pipe equal to or larger than 24-inch diameter pipe. Most of the pipe larger than 24 inches in diameter is brick pipe.

Of the pipe in the 2000 HB PDR Area that is smaller than 24 inches, approximately 15 percent (8,700 linear feet) is comprised of VCP and 21 percent (13,000 linear feet) is asbestos cement pipe (ACP). In Sewer Area 40, nearly 40 percent of the pipe is VCP and 6 percent is ACP. These two pipe materials have exhibited problematic early failures in other sewer systems and may be at the end of their useful material life and/or may be sources of excessive infiltration. Accordingly, the City may want to examine these pipe segments and consider holistic replacement and/or installation of a Cured-in-Place-Pipe Lining (CIPP) liner to protect the pipe during construction and extend its useful life. More discussion on rehabilitation will be introduced in Section 3.

Table 2.1 Lowell Combined System Pipe Material Summary

Pipe Diameter	Pipe Material (linear feet)							Total
	VCP	ACP	PVC	Conc	Brick	CIP	Unknown	
2000 HB PDR Area								
Unknown	410	631		136	926	43	494	**2,639**
8-inch	1,901		406	2,792			595	**5,694**
10-inch	648	215	251	4,490			3,550	**9,154**
12-inch	4,999	8,548		2,115			5,721	**21,383**
14x18					125			**125**
15-inch	1,128	2,585	201	1,979	46		1,312	**7,250**
16.5-inch				55				**55**
18-inch		1,110					1,922	**3,032**
24-inch				1,762	403		90	**2,256**
33x22					520			**520**
36-inch				627				**627**
37x25					689			**689**
39x26					217			**217**
48-inch				1,047	4,552			**5,599**
54x46					209			**209**
60-inch					2,011			**2,011**
96-inch				280				**280**
							2000 HB PDR Area Total	**61,741**
Sewer Area 40								
Unknown	633	298						**931**
8-inch				165			474	**639**
10-inch	3,132						1,725	**4,856**
12-inch	3,580	738		1,655			3,086	**9,060**
15-inch	1,125						564	**1,689**
18-inch	78	315						**393**
24-inch				744				**744**
27x18					1,918			**1,918**
30-inch					650			**650**
48-inch					924			**924**
54x46					633			**633**
							Sewer Area 40 Total	**22,436**

Figure 2.7 provides a plan depiction of the pipe materials in these sewer areas.



Legend

Sewer Gravity Main

Material

- VCP
- ACP
- Brick
- CIP
- PVC
- CONC
- UNK
- CIPP Lined Pipe
- Sewer Area 40
- 2000 HB PDR Area

CDM Smith

DUCK ISLAND — LOWELL REGIONAL WASTEWATER UTILITY

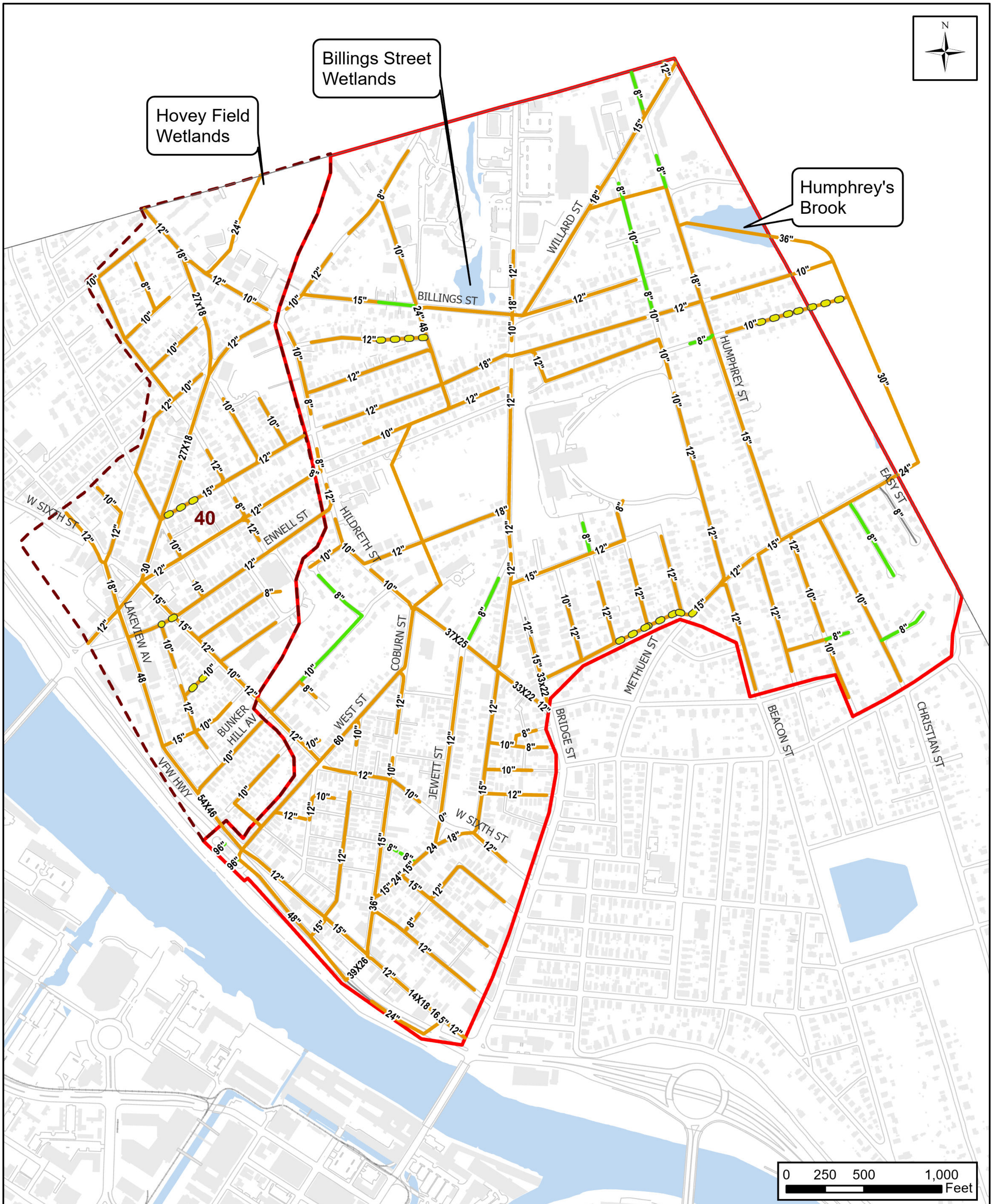
Lowell, Massachusetts

Centralville Sewer Separation PDR

Figure 2.7

Pipe Material

Figure 2.8 shows the existing pipe age distribution in the 2000 HB PDR Area and Sewer Area 40. Much of the existing piping system was built in the late 1800s and early 1900s; a significant majority of the pipes are over 73 years old (approximately 90 percent). These pipes are nearing the end of their useful life (especially considering the additional time required to replace or to rehabilitate this pipe). Section 3 considers the age of the system further along with the pipe material in developing a system rehabilitation plan.



Legend

Sewer Gravity Main

Date Installed

1951 - 2021 (2 - 72 Years Old)

1836 - 1950 (73 - 187 Years Old)

Unknown Age

CIPP Lined Pipe

Sewer Area

40

2000 HB PDR Area

CDM Smith

DUCK ISLAND LOWELL REGIONAL WASTEWATER UTILITY

Lowell, Massachusetts

Centralville Sewer Separation PDR

Figure 2.8

Pipe Age

2.3.4 West Station CSO Diversion Structure and West Pump Station

The West Station identified on **Figure 2.9** shows a location plan of the components that include the West Pump Station and CSO Diversion Structure in the median of the VFW Highway, and the West Station Outfall that discharges to the Merrimack River.

The West Pump Station was originally constructed by the U.S. Army Corps of Engineers (USACE) after significant river flooding occurred in the City during the 1936 storm. The flood improvements included an earthen levee and concrete I-wall system to protect the low-lying Centralville area just to the north of the pump station. The pump station was designed to discharge combined sewer flow from the Centralville area into the Merrimack River. The pump station includes a gravity and a pumped head discharge of sewer flow via the same outfall.

Lowell, Massachusetts
Centralville Sewer Separation PDR
Figure 2.9
West Station CSO Diversion Structure and West Pump Station

In the 1970s, the Duck Island and the North Bank Interceptor were constructed, along with the West CSO Diversion Station. Flow from the 96-inch diameter North Bank Interceptor and flow from Centralville (including the Humphrey's Brook drainage area in Dracut) are conveyed into the diversion structure. Dry-weather flow and a portion of the wet-weather flow is passed through this structure into the lower segments of the North Bank Interceptor. Excess wet weather flow is diverted to the gravity CSO outfall via a CSO diversion sluice gate in the structure; the sluice gate is remotely and automatically actuated. If river levels are high, greater than 54.0 Water Surface Elevation according to the USGS Gage Datum, the West Pump Station could be activated. **Figure 2.10** shows a schematic of the flow path around these facilities.

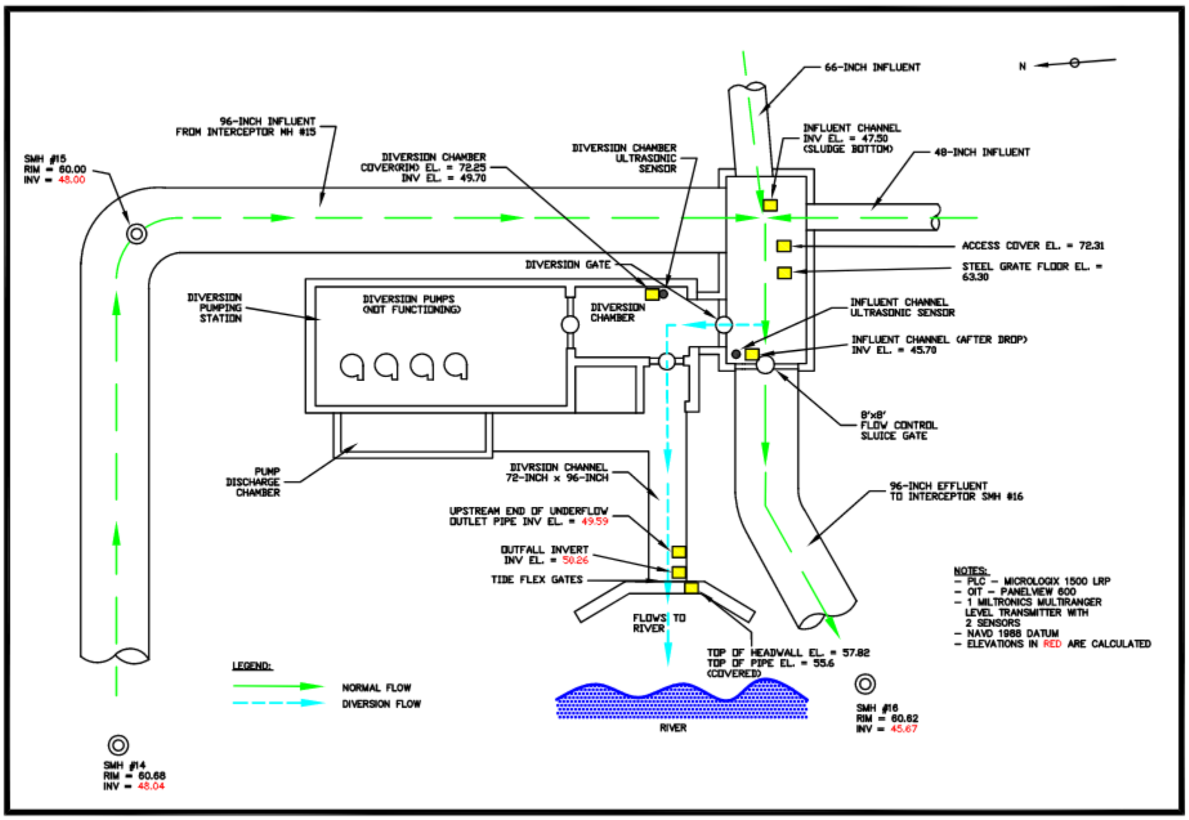


Figure 2.10 Flow Schematic for the West Pump Station and CSO Diversion Structure

The West Pump Station was inoperable for several decades starting in the 1970s. During an inspection by USACE in 2007, several deficiencies were noted regarding the inoperable state of the West Pump Station. Studies were completed to determine the improvements necessary to reactivate the station including an assessment of the effective pump capacity required to meet the Federal Emergency Management Agency (FEMA) standards for flood protection and re-certification of the Flood Insurance Risk Maps for this low lying area upstream of the station.

It was determined that rehabilitation of the pump station was the most cost-effective approach to return the station to its functional status and that the effective station capacity should be 60 mgd. Station Improvements were completed in 2018.

In addition to the station, a new structure was added to the North Bank Interceptor, downstream of the West Station near the Read CSO Station, to allow LRWWU to use inline interceptor pipeline storage using an automated inline flow control sluice. Currently, the flow control gate at the North Bank Flow Control Station is operated to store flow in the 96-inch interceptor pipe. Flow depth will increase during inline storage use at the CSO Diversion Structure. When flow depths exceed certain limits, the CSO Diversion Structure sluice gate will open to discharge excess wet weather flow as CSO to the gravity outfall or to the West Pump Station.

2.4 System Surcharge and Street Flooding Conditions

2.4.1 Overview

It is important to understand the current level of system surcharging and street flooding in the study area to implement system improvements that could mitigate these conditions.

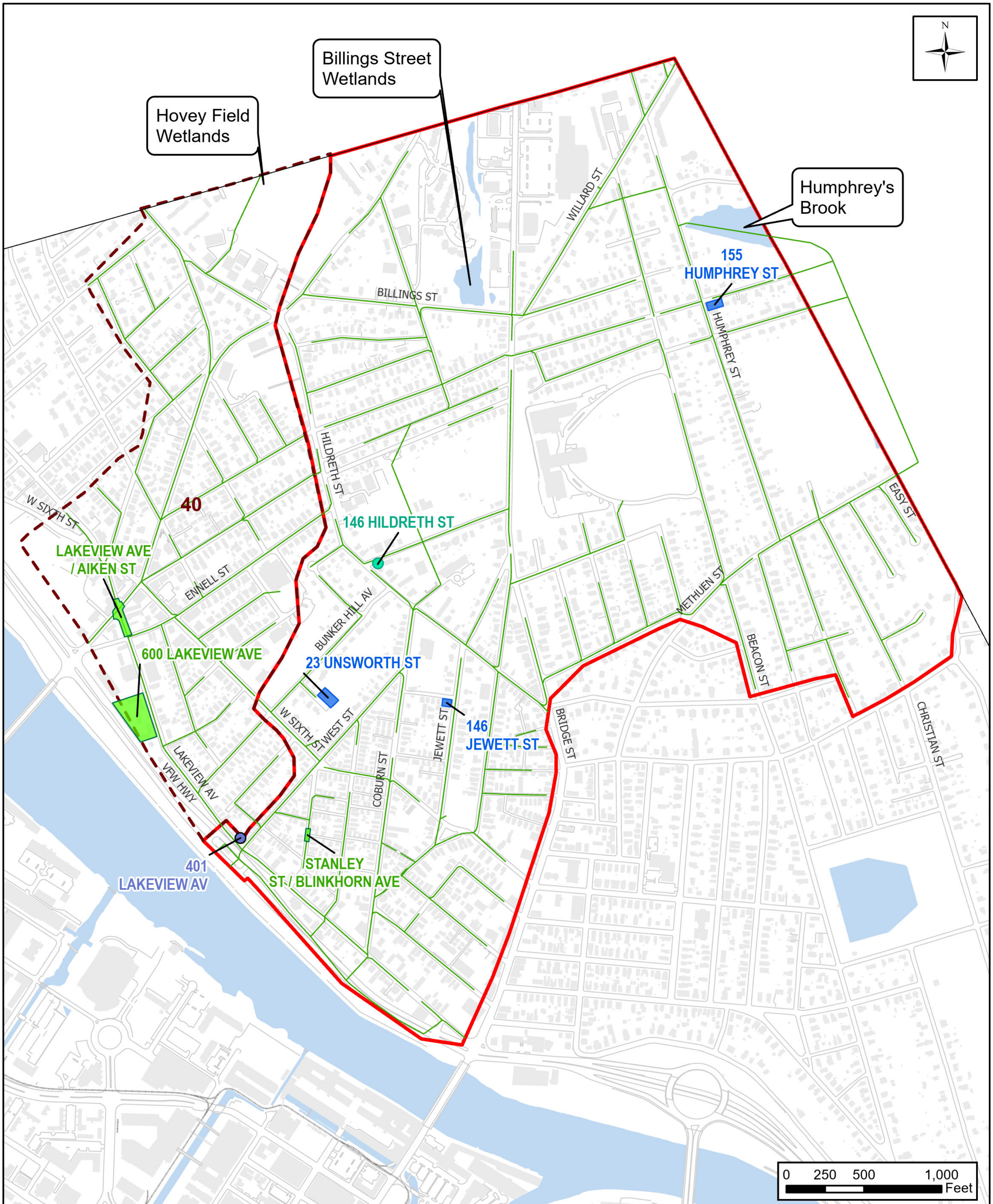
Street and/or basement flooding commonly occurs in combined sewer systems as a result of:

- Limited capacity of the existing combined system to handle wet-weather flows,
- Limited capacity of catch basins to allow flow into existing piping,
- Existing topography (low-lying areas), and
- High groundwater.

Depending on the intensity of a given storm, the existing combined system may surcharge and cause flooding in low-lying areas. Surcharging occurs when the capacity of a given piping system is exceeded, causing the hydraulic grade line (HGL) of the system to rise above the crown of a given pipe. The height of the HGL can be readily observed at drain or sewer manholes along the surcharged section. Under surcharged conditions, combined systems often flood basements and low-lying homes.

Several sources of information were used to identify and document existing adverse system conditions. These included reported street flooding conditions after historic and recent storm events, the Commonwealth of Massachusetts Sanitary Sewer Overflow (SSO) Notification Forms, staff discussions, and the online Sewer Issues and Street Flooding Survey. This survey was recently deployed on LRWWU's website to solicit and catalogue public input on a variety of sewer/collection system related issues for this study and the ongoing Phase 3 Sewer Separation Preliminary Design Report.

Figure 2.11 shows a summary of these wet weather issues.



Legend

- Sewer Gravity Main
- Sewer Area 40
- 2000 HB PDR Area

Public Input: Lowell Sewer Survey

- Sewer Backup/Property Flooding
- Roadway Flooding

Other Sources of Surcharge

- Flooding Reported to City
- LRWWU SSO Tracking

CDM Smith

DUCK ISLAND LOWELL REGIONAL WASTEWATER UTILITY

Lowell, Massachusetts
Centralville Sewer
Separation PDR

Figure 2.11
Reported Surcharges

2.4.2 Street and Property Flooding

Historically, parts of the 2000 HB PDR Area have experienced flooding during storm events. **Figure 2.12** and **Figure 2.13** show recent examples of street flooding in 2023.

Figure 2.12 Flooding at Stanley Street and Blinkhorn Avenue during a Summer 2023 storm

Figure 2.13 Flooding at Lakeview Avenue and Aiken Street during a Summer 2023 storm.

2.4.3 SSO Notification Forms

In a combined sewer system (CSS) if there is a discharge of sanitary sewer or combined flow to the surface, especially to a surface water, it must be reported to MassDEP via the SSO Notification Forms. LRWWU can be alerted to an SSO event by level monitors installed at key locations of known sewer surcharges, property owners reporting a discharge by phone, or by Civic Plus notifications submitted by residents.

After a notification of the condition, LRWWU must make a field inspection, complete cleanup, assess the situation, and complete and submit the SSO notification form to MassDEP within five days.

Figure 2.11 shows a summary of the wet-weather related SSOs that occurred in the study area for 2023.

In 2023, the vast majority of the 49 SSO events in Lowell occurred via surcharged combined system manholes. However, there was only one SSO event within the 2000 HB PDR Area and Sewer Area 40; this occurred at 401 Lakeview Ave, where a sanitary sewer manhole surcharged in the street. There were no reported basement back-ups into properties in the 2000 HB PDR Area and Sewer Area 40.

2.4.4 Public Input

LRWWU has created an online Sewer and Street Flooding Issues Survey, available in English, Spanish, Portuguese, and Khmer (https://www.lowellma.gov/637/Wastewater-Utility), to actively solicit input on adverse sewer system conditions within the City. **Figure 2.14** shows the first page of this online survey. Residents, visitors, and property owners in Lowell will be notified of the availability of this survey via mailings, public notifications, newspaper articles, website notifications, and electronic media postings.

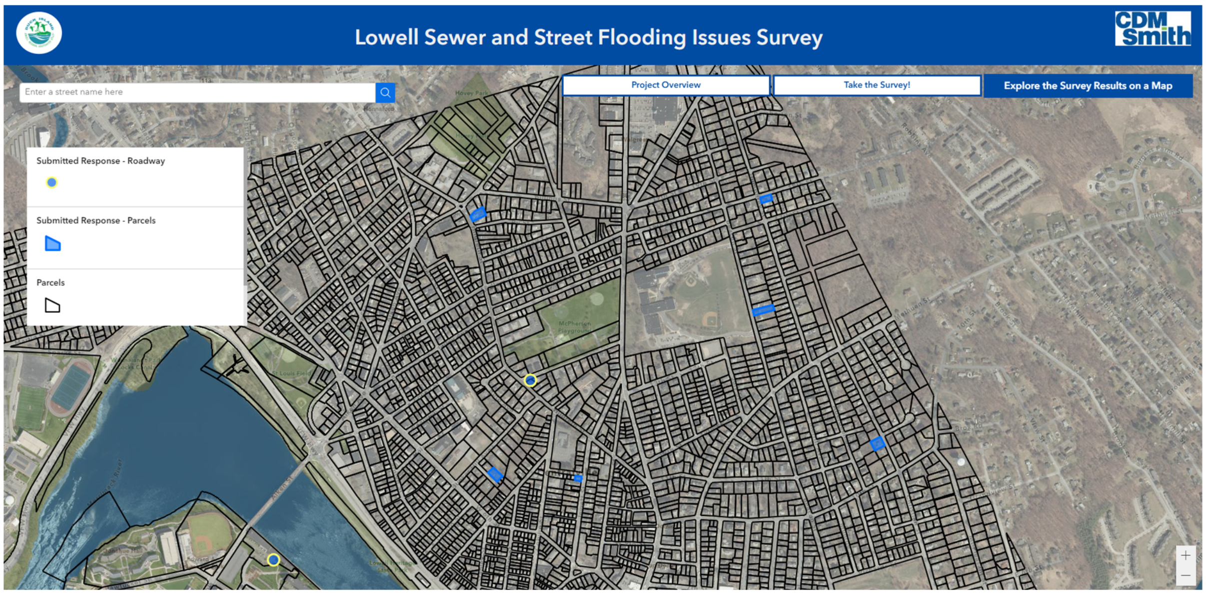


Figure 2.14 Online Lowell Survey

The survey allows the public to provide valuable first-hand experience on how the existing combined sewer system operates and the data collected through this survey will be beneficial in prioritizing future system improvement projects. The survey includes questions on the presence of sump pumps in the building, historical basement flooding, and adjacent street flooding. It provides a platform for residents, property owners, and visitors to report on issues in the City.

Seven responses have been received so far in the Humphrey's Brook study area. Figure 2.11 shows locations where flooding has been reported.

- Flooding has been observed at McPherson Playground on Richardson Street (reported by 146 Hildreth Street),
- Sewer backup and leakage are reported at 155 Humphrey Street,
- 146 Jewett Street reports flooding on the property that started in 2023, that prevents parking, and
- 23 Unsworth Street reports that there is sewer flooding on the property.

2.5 Utility Replacement Needs

The existing combined sewer system in the 2000 HB PDR Area and Sewer Area 40 is primarily located along the centerline of the street. Most streets also contain a water main on one side of the combined sewer and a gas main on the other. To accommodate some of the larger lateral drains, either a gas or water main will need to be relocated to develop a dedicated corridor for the new pipe. These relocations will be identified as part of the final design process. Based on experience, conflicts with electric conduit and telephone duct relocations are usually avoided because of the long lead time to coordinate and complete relocation of these utilities.

Many of the existing water mains in the 2000 HB PDR Area and Sewer Area 40 are older cast iron, which may be susceptible to damage during construction due to vibration or excavation if too close to the work. On a case by case basis, cast iron water mains that will not be relocated could be replaced with a new ductile iron water main or lined with a structural liner (if practical). LRWWU will work with the Lowell Regional Water Utility to identify water main replacement needs for the project and overall City infrastructure renewal.

Gas mains may also need to be relocated or replaced to accommodate new work. In many cases, the gas utility (National Grid) may be responsible for the gas main work, especially to replace older, cast iron gas mains, which are typically removed by the gas company as part of their infrastructural renewal to minimize leaks. National Grid will be contacted during design to coordinate the infrastructure renewal needs prior to construction because the gas main relocations are typically completed first. To the extent practical, the work will avoid the relocation of high pressure and large diameter gas mains to minimize construction challenges.

3.0 System Rehabilitation Needs

3.1 Introduction

Aging wastewater collection system infrastructure is a challenge for wastewater utilities. Historically, many utilities operated with a run-to-failure management approach that caused assets to deteriorate faster and resulted in higher replacement and significant emergency response costs. Proactive operation and maintenance programs are the key to addressing this challenge, which includes taking an active approach to sewer system rehabilitation. Lowell has been a leader in proactive maintenance of collection system assets, with over $1.5 Million annually spent on collection system maintenance and refurbishment programs. Activities under this program include regularly cleaning sewers (average of 10,000 linear feet over the last 5 years), identifying and monitoring problem areas (through methods such as CCTV inspections and SSO reporting), repairing failing sewers, pump station inspections, and implementation of I/I study and an SSES program.

The need for collection system rehabilitation or upgrades arises from several factors:

- Deterioration of the structural integrity of an aging combined sewer system,
- Excessive infiltration and inflow (I/I) due to defects in the systems,
- Increasing regulatory control of wet weather overflows from sewer systems,
- Additional hydraulic capacity needs for the combined sewer system, and
- New construction in close vicinity to aging combined sewer pipes.

These factors are magnified in an area like the 2000 HB PDR Area where, as discussed in Section 2, most of the pipe was installed before 1950. Pipes of that age are reaching the end of their useful life and the pipe material used in these older installations are prone to settlement (causing joint issues), cracking/fracturing, and broken and collapsed pipe segments. The City has a significant quantity of brick sewers that also present issues such as missing brick and walls that can contribute to groundwater infiltration and external pipe circumference voids that can lead to street collapses.

There are two reasons for LRWWU to address this aging pipe issue – one is to rehabilitate or replace the aging pipes before they fail and the second is to eliminate sources of extraneous flow that can pour into sewer defects. The 2023 Draft Consent Decree requires the Utility to develop and implement an I/I reduction program to reduce this extraneous flow. Integration of a pipe rehabilitation plan into the sewer separation program for complete infrastructure renewal is a cost-effective approach.

The prerequisite for system rehabilitation is a comprehensive condition assessment of the piping system. The condition assessment provides the background to evaluate the existing system, characterize the defects and severity, and identify other deficiencies. Once the condition assessment is complete, system rehabilitation needs should be evaluated against available rehabilitation technologies to determine the best approach for infrastructure renewal. This section addresses the condition assessment and rehabilitation needs for the existing combined sewer system.

3.2 Condition Assessment

3.2.1 Introduction

Extraneous flow (i.e., flow not discharged by residents or businesses) can enter a collection system as infiltration (indirect) or inflow (direct). Infiltration is groundwater that enters the sewer system from defects in mainline or property services pipes and joints, sources of infiltration may include rivers, brooks, and streams. Lowell continues to investigate its interceptor system for sources of extraneous flow due to the proximity of the interceptors to the river and the range of river depths along the river banks relative to the interceptor. Infiltration typically increases as pipes age and/or fall into disrepair.

Inflow is generally a factor of rainwater entering the system from public sources like catch basins (CBs) or from private sources such as roof leader (gutters), yard/ driveway drains, or foundation drains that are connected to the sewer system. Some buildings may also have sump pumps that take groundwater seeping into basements and discharge it to the sewer. Inflow can also include a continuous source of extraneous flow to a sewer such as a brook or stream. These extraneous flows can substantially reduce the dry and wet weather capacity of the existing system.

During a sewer separation project, attention should be given to identifying and reducing or eliminating all extraneous flows to the system. However, while a new drain system will readily eliminate public CB flow to the sewer system, other sources of extraneous flow are more difficult (and costly) to identify and eliminate.

In addition, for this project, new sewers and/or drains will have to be installed in tight corridors where excavation could potentially damage or conflict with existing sewer pipes. Excavation near sewer pipes that are in poor condition can result in a structural failure resulting from vibration from machinery or pipes being unsupported near excavated trenches. Accordingly, the condition of the existing pipe, and its need for rehabilitation/replacement, should be assessed before construction begins.

Comprehensive field investigations were performed on the existing combined sewer system (CSS) in the 2000 HB PDR Area to develop a representative picture of overall system conditions. CDM Smith, with the support of Wright-Pierce, completed these investigations, which included closed-circuit television (CCTV) inspection and review of the CSS, manhole inspections, smoke testing, and windshield/desktop surveys to look for potential building sources of inflow for the purpose of identifying needed repairs and rehabilitation.

3.2.2 Television Inspections

CCTV of the CSS was performed by Inland Water/Green Mountain Pipeline Services (GMPS) as a subcontractor to Wright-Pierce during Spring and Summer of 2023. Specific pipe sections were selected for inspection based on size, age, material, and location within the system. CCTV inspections were performed for approximately 25,000 linear feet of pipe. LRWWU provided an additional 2,500 linear feet of pipe CCTV, which was completed over the last 5 years.

Inland Water/GMPS performed inspections of the sewer pipe according to National Association of Sewer Service Companies' (NASSCO) Pipeline Assessment Certification Program (PACP) standards. Pipe cleaning was performed before the inspection, as necessary, to maximize the value of the inspections.

The CCTV camera travels through the pipe to identify structural and maintenance defects such as fractures, breaks, deformation, sedimentation/debris, infiltration, and lateral locations. The video from the inspection and defect codes are recorded and used to generate an inspection report for each pipe segment.

Once an inspection report is developed for the pipe, a likelihood of failure (LoF) rating was assigned to each defect according to NASSCO PACP standards. This is a numerical representation of the pipe's physical condition and probability of failure. It should be noted that NASSCO LoF ratings are more heavily weighted on structural defects compared to maintenance and operation defects which infiltration codes fall under. Wright-Pierce used a sewer asset rehabilitation software using the LoF ratings and defect types to generate preliminary recommendations for each pipe segment. The program recommendations were then reviewed to confirm or revise the results and recommendations.

LRWWU also provided historical CCTV inspection that they completed over the last five years. The LRWWU videos did not have an inspection report or NASSCO coding, so Wright-Pierce engaged Sewer AI to complete an automated defect recognition (ADR) technology pipe assessment. This is an emerging artificial intelligence (AI) process/approach that uses machine learning technology to identify defects from CCTV videos. The ADR process uses the NASSCO PACP standards as a guide for coding defects but the software is not certified by NASSCO. Once PACP coding was complete, Wright-Pierce used this information in its software program to generate recommendations for the inspected subset of pipes.

In total, just under 50 percent of the total (CSS) piping was examined during this program.

3.2.3 Manhole Inspections

Manhole inspections were performed by Wright-Pierce in the Summer of 2023 to assess the structural condition of the manholes and identify potential visible sources of I/I. Manhole inspections were completed on 243 manholes using the NASSCO Manhole Assessment Certification Program (MACP) Level 1 standards.

A Level 1 inspection involves the completion of an above grade inspection using a form to record the location of the manhole and basic features including the material and condition of each component of the manhole, and pictures of the structure. The focus of this inspection was on the integrity of the manhole and not the confirmation of pipe inverts, materials, and diameters.

Wright Pierce also used a 360-degree high-definition pole mounted video camera to record the conditions in each manhole and to examine with the zoom camera capability the upstream and downstream pipes. The zoom camera can be useful to assess pipe condition but factors such as pipe size, material and lighting can limit visibility (typically between 10 to 30 feet). Based on the MACP Level 1 inspection, each component was given a condition rating of sound or defective. Manholes with a defective condition rating were then evaluated to determine if rehabilitation is required.

Nearly 70 percent of the manholes were found to be in good overall condition with no further action needed. The remaining 30 percent of manholes were found to need either lining or point repairs, but no manholes were identified to require a full replacement.

3.2.4 Smoke Testing

Smoke testing is typically used in a sanitary sewer system to identify potential sources of inflow into the sewer system. Smoke testing is not typically performed on a CSS as the primary source of inflow is from CBs, which are also the primary emitter of the testing smoke. However, smoke testing has been completed in other CSSs successfully to identify other private sources of inflow (such as roof downspouts, floor drains, yard drains, and area drains). Accordingly, this field work was completed as a demonstration test with plywood covering CBs to minimize smoke leakage.

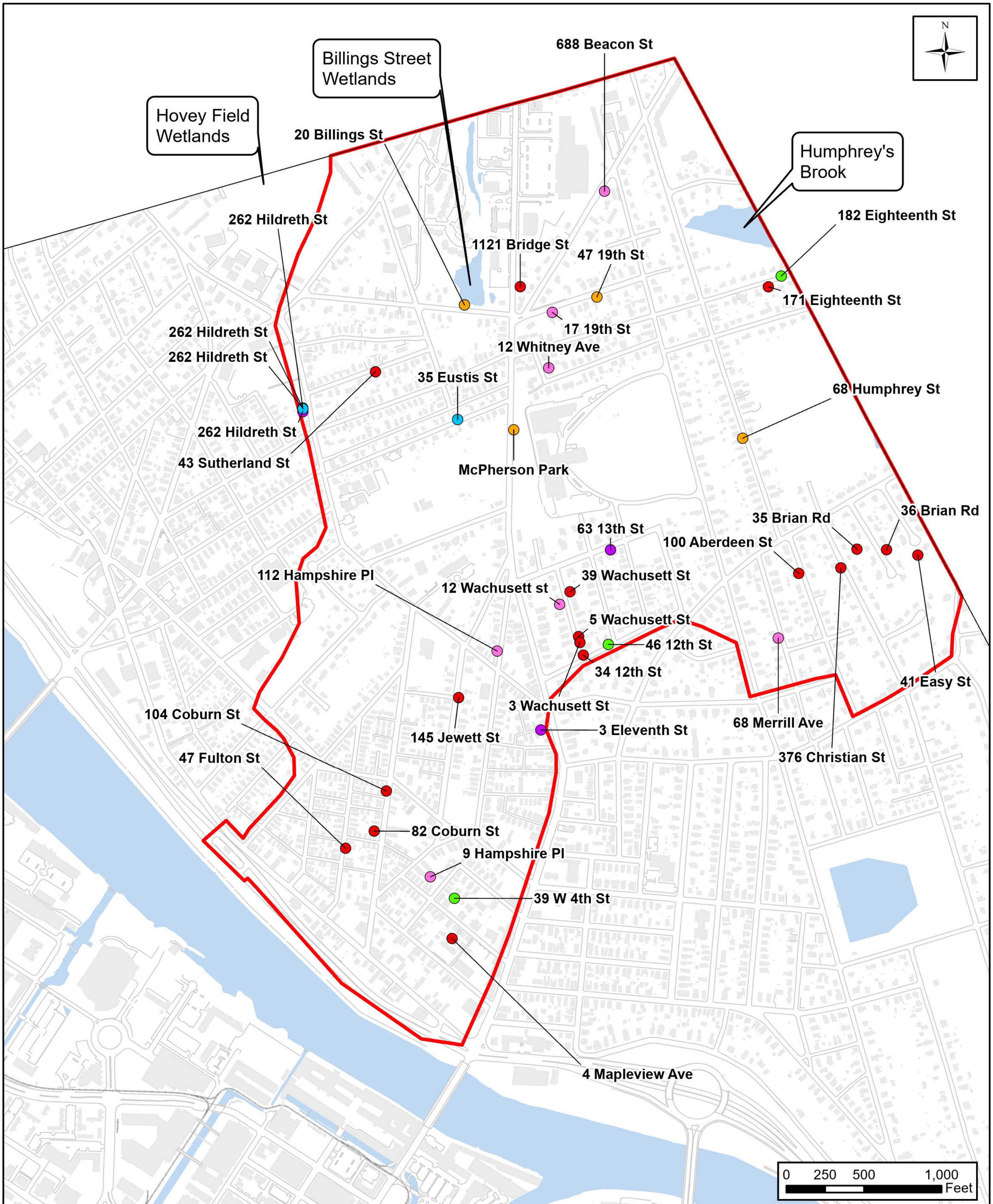
Wright-Pierce performed the smoke testing program for the 2000 HB PDR Area in the Summer of 2023. Smoke testing is conducted by isolating pipes and using a blower to fill the sewer system with non-toxic smoke. The inspector then observes the area for locations where smoke is present. Results of the smoke testing program are summarized in **Table 3.1.**

Table 3.1 Smoke Test Results

Source	Count
Driveway Drain	3
Home/Structure/Building	24
Ground	6
Yard Drain	1
Other	3
Total	**37**

In general, a relatively low number of potential private inflow connections were discovered and these sources were widely distributed. Only 37 sources of smoke not sourced from a catch basin, manhole, or sewer cleanout were identified. Of those 37, only four were directly linked to a confirmed source (driveway/yard) drain. The remaining 33 locations will require further investigation to determine the source such as conducting building inspections or dye testing.

Figure 3.1 shows the results of smoke testing program.



Legend

Preliminary Recommendation
- Building inspection
- CCTV lateral inspection
- Redirect source as stormwater flow
- Dye test
- Property owner to repair
- No action (Assumed dry P-trap)

2000 HB PDR Area

CDM Smith

DUCK ISLAND LOWELL REGIONAL WASTEWATER UTILITY

Lowell, Massachusetts

Centralville Sewer Separation PDR

Figure 3.1

Smoke Testing Program

3.2.5 Desktop/Windshield Survey for Potential Inflow Sources

To complement the smoke testing program, a windshield survey/desktop analysis was also completed. Initially, the City's GIS and photogrammetry were used to identify flat building roofs. This was followed by a field visit during September 2023 to examine each of the buildings with flat roofs to identify visible external roof drains or scuppers that direct roof runoff to the ground or pipes into the ground. During this field program, additional buildings were identified with potential flat roofs that were not picked up in the desktop analysis.

Figure 3.2 shows the location of over 50 buildings with flat roofs having no visible roof drain or scupper within the 2000 HB PDR Area. It is suspected that these flat roofs have internal building drains that could connect to the sewer service. During final design and/or construction, building inspections and dye testing will be completed to identify if extraneous flow connections to the sewer system can be cost effectively disconnected.

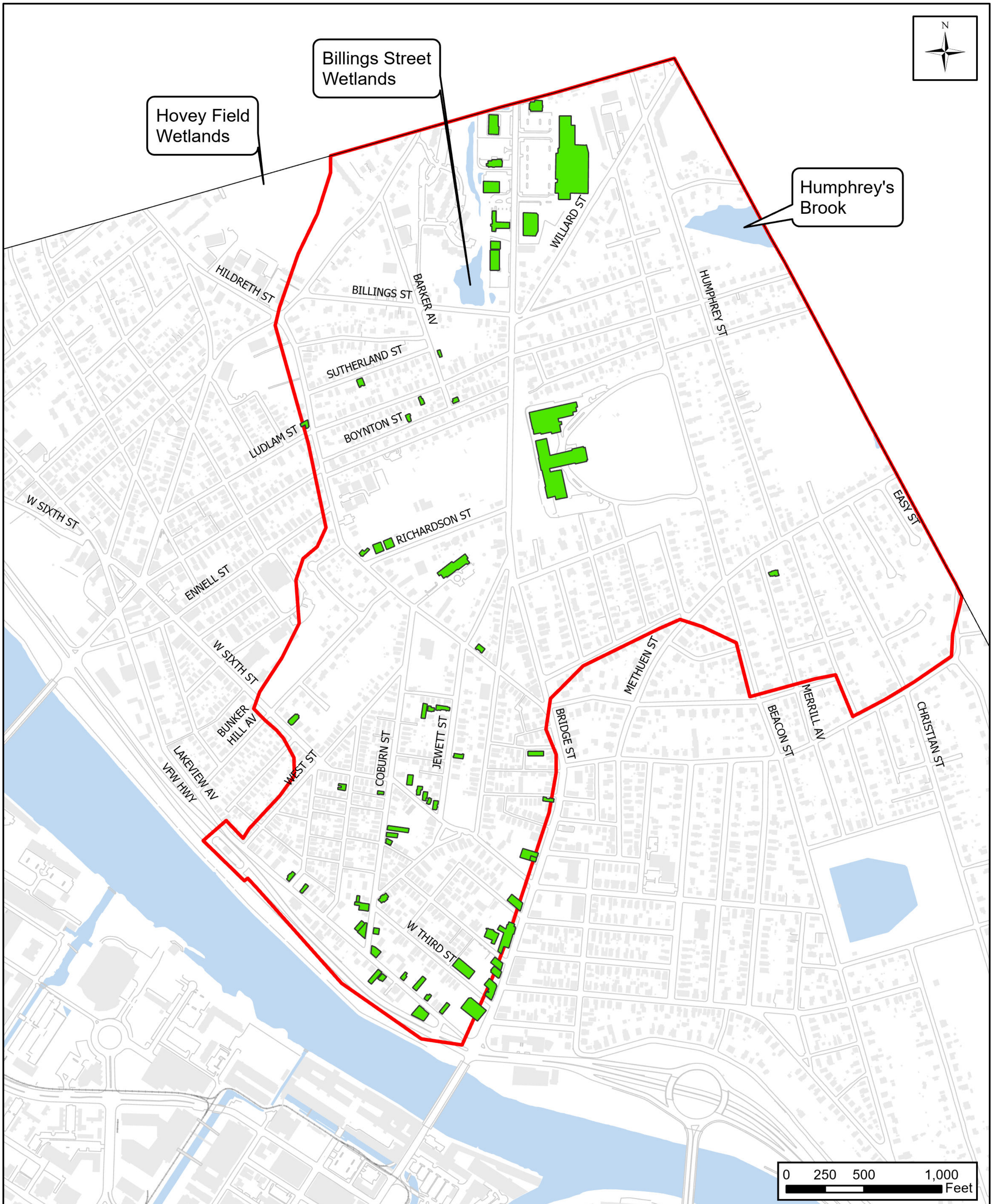
3.3 Trenchless System Rehabilitation Approaches

3.3.1 Overview

While open cut excavation and complete pipe segment replacement is always an option, rehabilitation of existing sewer pipes, manholes, and service laterals is increasingly being accomplished with trenchless methods. Trenchless rehabilitation methods can be used to reduce I/I and extend the service life of the pipe and are typically structurally independent of the host pipe. Depending on project-specific situations, trenchless pipe rehabilitation techniques offer a variety of potential advantages over traditional open-cut pipeline replacement techniques, such as:

- More cost-effective than open cut,
- Avoidance of many surface constraints,
- Disruption of other services minimized,
- Surface reinstatement needs minimized,
- Surface disruption including traffic disruption kept to a minimum,
- Reduced surface settlement, and
- Environmental disturbance minimized.

It is important to note that the pipe and manhole inspections were evaluated based on NASCCO standards, which are focused on the structural condition and potential failure of the pipe. The Utility is currently developing an I/I Analysis Report that will utilize data obtained from a comprehensive flow metering program, conducted in 2023, to identify the sewer subareas with excessive I/I. Each of these pipe, manhole, and sewer lateral rehabilitation strategies will help to mitigate extraneous flow entering the system through some of the defects noted in the NASCCO grading.



Legend

Flat Roof

2000 HB PDR Area

Lowell, Massachusetts

Centralville Sewer Separation PDR

Figure 3.2

Potential Inflow Sources from Flat Roofs

3.3.2 Sewer Pipe Rehabilitation

For this project, a cured-in-place pipe (CIPP) will likely be the preferred method of pipe rehabilitation. CIPP liners can be used both for structural and non-structural (for the purpose of I/I reduction) rehabilitation of sewer lines. The CIPP liner consists of a tubular felt-like material saturated with an epoxy resin that, after curing, turns in to a rigid liner for the pipe. Before the process is initiated, pipes must be thoroughly cleaned (and roots removed) and dried.

A CCTV camera inspects the pipe to ensure the pipe wall is clean and ready for installation of the liner. In addition, the locations of service lines are documented during the CCTV operation. After the lining is installed and cured, a CCTV camera will be run through the pipe to inspect the condition of the liner and reinstate the lateral connections by a robotic machine.

Based on the extensive record of CIPP rehabilitation and the numerous trenchless contractors proficient at installing this technology, any recommended plan for rehabilitation of pipelines will typically use CIPP as its rehabilitation solution. Other methods such as sliplining, fold and form lining, spirally wound pipe, or segmental lining may be considered on a case-by-case basis during the design process.

3.3.3 Sewer Replacement and Point Repairs

Sewer replacement is generally considered when additional hydraulic capacity is required or lining is not feasible due to significant pipe defects. If a pipe is generally in good condition except for a few short sections, then point repairs of the deficient sections can be used. It should be noted that point repairs will not completely reduce I/I in that segment, but the use of trenchless methods may not be possible if the pipe has defects such as a collapsed or partially collapsed pipe segments, large holes, broken pipe with voids in the pipe bedding, missing brick, offset or separated pipe joints, or large obstructions exist. In these cases, the pipe segment could be repaired through a point repair, and left alone, or full CIPP liner of the pipe from manhole to manhole could be completed.

3.3.4 Service Lateral Rehabilitation

Service laterals can be a major source of private I/I into the collection system, with some estimates as high as 50 percent of total I/I contributed by service laterals. Wastewater utilities have found that an effective lateral rehabilitation program can significantly reduce the I/I in a system. In Lowell, the city only owns the sewer main, and private property owners own and are responsible for their lateral from the building to the connection point at the main. This could create a challenge when navigating any rehabilitation work on private sewer laterals.

The following methods are available for sewer lateral rehabilitation:

- Removal and replacement,
- CIPP lining,
- Chemical grouting, and
- Pipe bursting.

3.3.4.1 Removal and Replacement

Open cut removal and replacement of sewer laterals is a proven method for renewing sewer laterals. The old service line may either be abandoned in place or removed. This technique is cost-effective when dealing with relatively shallow services and where there is no elaborate landscaping or obstacles such as fences, paved driveways, or sidewalks. However, in many communities, private property owners are financially responsible for maintenance of sewer laterals from the source to the mainline. Sewer lateral replacement is recommended when the structural condition of the pipe has failed, or structural defects allow excessive infiltration to enter the system. Pipe replacement is also recommended in areas where the pipe has not failed but is severely deformed or misaligned, so it Is not possible to use trenchless techniques.

3.3.4.2 Cured-in-Place Pipe (CIPP) Lateral Lining

The most common type of liner used for lateral rehabilitation is CIPP (cured-in-place pipe). Access to the service lateral may be from either the sewer line or from the cleanout. If a cleanout is not available, a small entry point outside the building can be made to install one. However, newer lining technologies can rehabilitate most of the service lateral from the main line sewer.

The process of liner installation in the service lateral is very similar to the CIPP lining of sewer lines. The lateral should be cleaned of all debris and roots. The liner is saturated with resin and pulled through the service lateral by either the inversion or winching method. The liner is then inflated and cured by either water or air. This method of rehabilitation is recommended when a sewer is structurally damaged or in danger of failure, as the completed liner will fully restore the structural integrity of a damaged pipe.

3.3.4.3 Lateral/Mainline Sewer Connection Rehabilitation

Since the junction between the service lateral and the sewer line is the weakest point, special measures are taken after the liner is installed so that the junction becomes watertight. Proprietary systems are available that rehabilitate the lateral/sewer line junctions while the lateral is rehabilitated. If both the sewer line and the lateral are to be rehabilitated, the mainline pipe should be rehabilitated first followed by the rehabilitation of the lateral, as this will minimize any damage to the liner.

Service connection and lateral liners are cured-in-place liners used to seal the service connection between the sewer main and lateral as well as some portion of the lateral. The liner, installed by remote device, typically consists of felt fabric and polyester resin. A short portion of the liner is placed in the sewer main around the full diameter, and a second portion is located a defined distance up the lateral. The two pieces are attached during the hardening process to form a complete sleeve that encompasses both the lateral and the mainline sewer pipe.

There are different techniques that can be used to rehabilitate the connection between the mainline and lateral. In instances where the mainline has already been lined with a CIPP liner, one method to rehabilitate the connection is to use a brim style liner, also known as a top hat liner (**Figure 3.3**).

A brim (top hat) liner forms a ring around the penetration for the lateral then extends from 6 inches to 2 feet up the lateral.

In situations where the mainline has not been lined, a technique known as a full wrap liner is typically used (**Figure 3.4**).

A full wrap lines a short section of the mainline before and after a lateral and then extends up into the lateral, similar to a brim style liner. This technique can also be used in situations where a mainline was previously lined and the service connection has been overcut or shifted to patch the liner (**Figure 3.5**).

Anytime a lateral connection is rehabilitated, it needs to be sealed. This is done with either Acrylamide or Urethane chemical grout. The grout hardens in the annular space between the mainline and connection, as well as along the edges of a brim (top hat) or full wrap liner. The average expected life expectancy of a lateral connection seal is five to twenty years.

3.3.5 Manhole Rehabilitation

Infiltration into manholes generally occurs due to cracks, loose/missing mortar at joints, or missing bricks. Deterioration due to corrosive sanitary sewer gases and microbiological growth can eat through the original cementitious walls and mortar causing leaks, erosion, and ultimately structural deterioration.

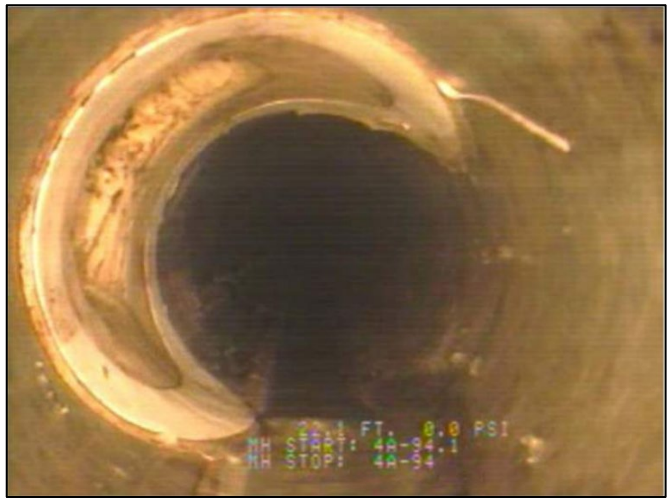


Figure 3.3 Brim Style liner

Figure 3.4 Full Wrap Liner

Figure 3.5 Shifted Service Connection/ Lateral

Inflow into a manhole can occur during storm events as the rainwater from the surface may enter the manhole through the cover, frame, or frame seal. Typical defects may include:

- The cover may have open vent or pick holes which are subject to ponding; the bearing surface may be worn or deteriorated; the cover may not fit properly; or the cover may be cracked, broken, or missing.
- The frame may be cracked, worn, or deteriorated.
- The gasket may be missing, or the frame may be offset from the chimney causing leakage between the frame and chimney joint.

Rehabilitation of manholes, including cover replacement for those that have an excessive number of pick holes, provides for removal of I/I sources and reduces the potential for SSOs. The following methods can be used for manhole rehabilitation:

- Chemical grouting. Grouts give best results in cohesive soils, and may be used to fill voids, stabilize soils behind manhole walls, or stop active infiltration prior to applying a coating system, but they are not warranted to improve the structural integrity of a manhole.
- Coating Systems. Coating systems may be used as a corrosion protection barrier, to enhance structural integrity of manholes, and to reduce I/I. These may or may not include full coating of the manhole.
- Structural lining. Structural rehabilitation can be performed to restore the integrity of badly deteriorated manholes. Structural rehabilitation consists of a monolithic cementitious or epoxy lining applied to the entire interior surface of the manhole. This is also an effective method to reduce I/I.
- Frame, cover, invert, and chimney rehabilitation. Rehabilitation under this category could include replacement of frame and covers due to defects or holes allowing I/I, point repairs to components of a manhole (chimney, wall, bench, etc.) or rebuilding an invert.

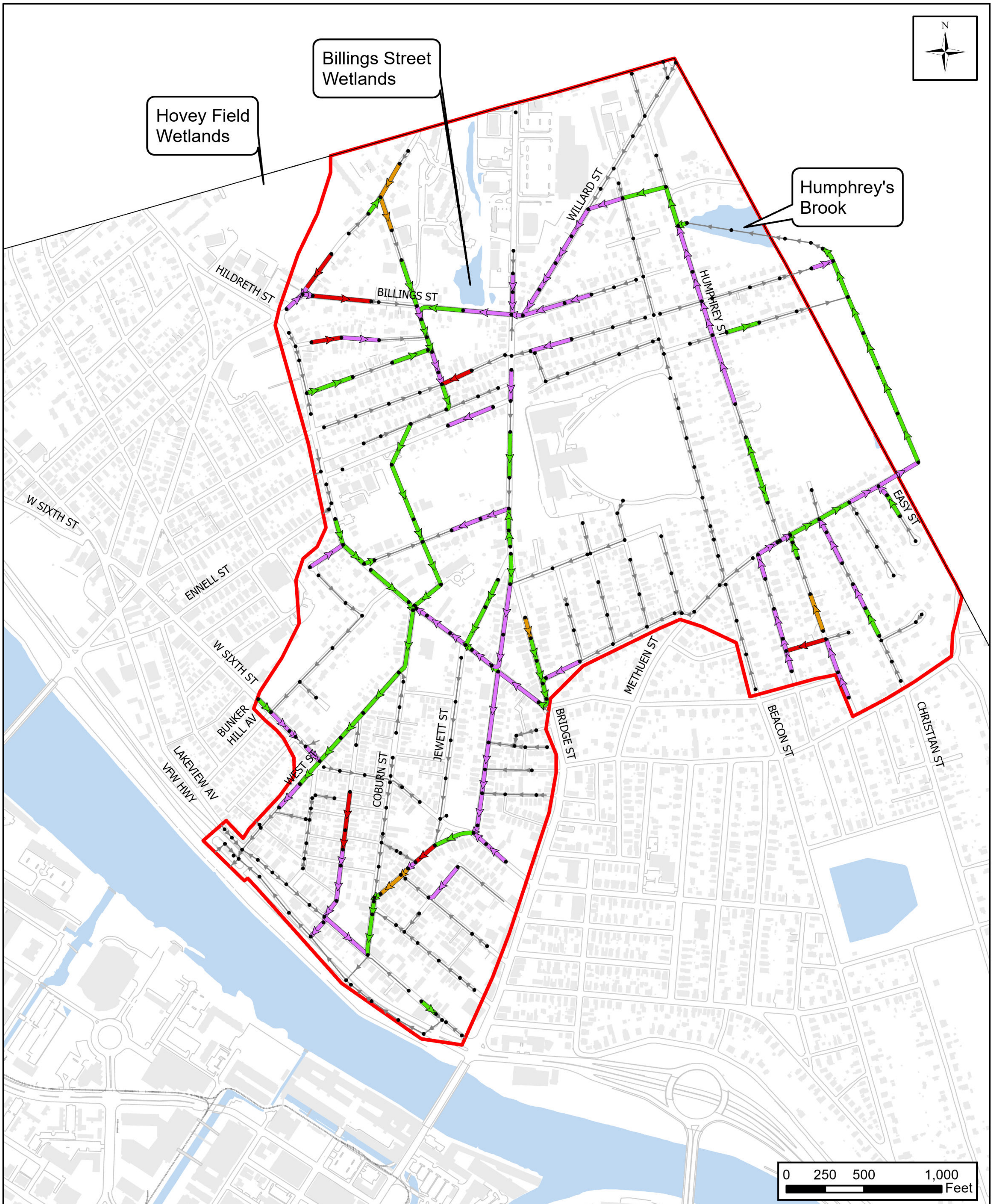
3.4 Conclusions/Recommended Rehabilitations

3.4.1 Pipeline Recommendations

The results of the CCTV inspection program discussed in Section 3.2.2 resulted in recommendations for approximately 28,000 linear feet of sewer pipe within the 2000 HB PDR Area. As pipe failures were identified, Lowell completed immediate repairs (one example is 18th Street). Four categories of repairs were recommended. The results can be found in the **Table 3.2** and are shown on **Figure 3.6.**

Table 3.2 Summary of Revised Preliminary Rehabilitation Recommendations

Preliminary Rehabilitation Recommendation	Pipe Length (LF)
No Action Required	11,879
Line	12,980
Point Repair	1,108 (11 pipes)
Replace	1,862
Total	27,830



Legend

Sewer Gravity Main

Preliminary Recommendation

- Replace
- Point Repair
- Line
- No Action
- No CCTV Performed
- Sewer Manhole
- 2000 HB PDR Area

Lowell, Massachusetts

Centralville Sewer Separation PDR

Figure 3.6

Preliminary Recommendations Based on CCTV Inspections

These recommendations represent pipes selected for this field program as a representative study. Of the pipes inspected, 46.6 percent were recommended for lining rehabilitation. The program also suggests that a smaller percentage of the system is in need of full replacement or excavated repairs. The recommendations from the television inspection program can be projected over the entire system to determine the rehabilitation needed over the entire 2000 HB PDR Area.

It is important to understand that these recommendations are based on the current condition of the pipes within the system and as time passes they will continue to degrade. Roughly 90 percent of the pipes in the 2000 HB PDR Area are older than 1950, or more than 73 years old. The expected useful life of sewer pipe varies based on its material, construction and installation method, subsurface conditions, frequency of use, and past disturbances. Expected useful life of pipes in the wastewater collection system are typically estimated to be 50 to 100 years old. Based on the age of the system, many of these pipes are at or nearing the end of their useful life. As part of infrastructure renewal for the Humphrey's Brook area, lining should be considered for a larger percentage of pipes to mitigate I/I and extend the useful life of the existing sewer collection system. This same approach should also be applied to other areas that were not inspected as part of this study.

Construction costs for pipe rehabilitation were estimated using a unit cost by pipe diameter, obtained from recent bid estimates. Recommendations from the television inspection program were used as a baseline for the estimate. As previously stated, that baseline was projected out over the system to develop a comprehensive cost. Lining of all pipes older than 1950 (which included all pipes recommended from inspection) was also considered.

Rehabilitation costs are presented in **Table 3.3** for a range of options:

- The second column presents the cost for lining just the pipes reviewed and recommended as part of the CCTV program,
- The third column presents the lining cost projected for the entire separation area, assuming that the rate of rehabilitation required for the pipes inspected thus far will be consistent,
- The fourth column presents the cost to line all pipes installed prior to 1950.

As a budgetary cost approach, it is suggested that the Utility consider that all pipes installed prior to 1950 (the fourth column) be lined as this option achieves infrastructure renewal and significantly extends the life of existing sewer collection system. The extent of actual pipe rehabilitation necessary for infrastructure renewal will be considered during final design.

Table 3.3 Cured-in-Place Lining Projected Construction Costs

	CCTV Recommended Lining (21.0%)	Projected Cost Extended for Full Area (46.6%)	Line all Pipes installed prior to 1950
2000 HB PDR Area	$4,562,000	$8,200,000	$16,200,000
Area 40	N/A	$3,000,000	$6,100,000

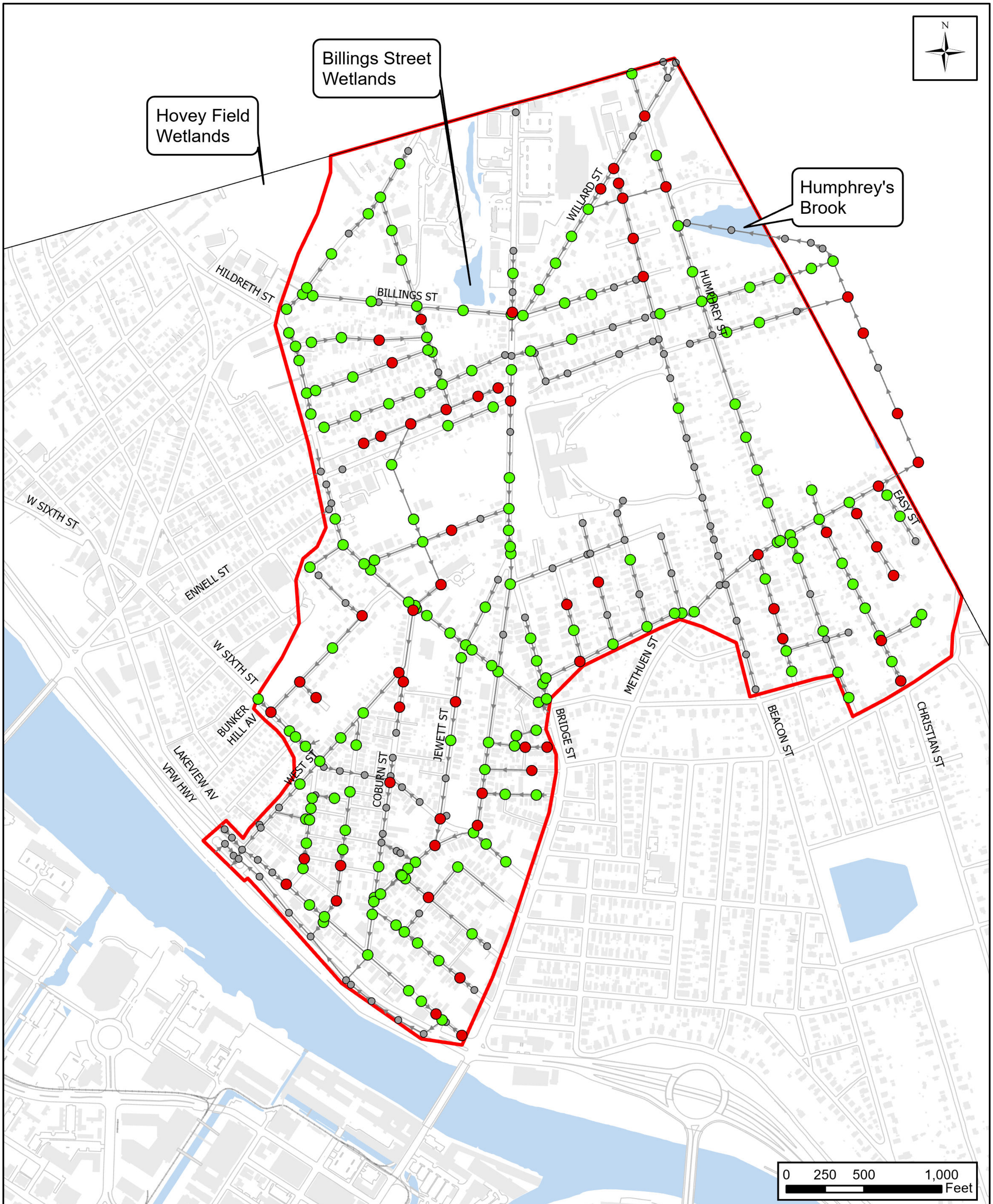
3.4.2 Manhole Recommendations

The manhole inspection program (discussed in Section 3.2.3) presented recommendations for the 243 manholes that were inspected during this program. These preliminary recommendations represent the future action that should be taken based on the severity of the manhole condition. **Table 3.4** summarizes those recommendations and the approximate construction cost of the recommendations based on recent bid estimates.

Table 3.4 Summary of Manhole Rehabilitation Recommendations

Preliminary Rehabilitation Recommendation	Number of Manholes	Estimated Cost
No Action	179	$0
Rehabilitation the manhole	63	$315,000
Replace the manhole	0	$0
Total	**242**	**$315,000**

Most manholes are recommended for "no action" meaning that most of the manholes are sound and do not need any further rehabilitation. Manholes that are recommended for rehabilitation have defects that will not require a full replacement of the manhole but may need a lining installed or require a point repair. These results are shown in **Figure 3.7.**



CDM Smith

DUCK ISLAND
LOWELL REGIONAL WASTEWATER UTILITY

Legend

Sewer Manhole
Preliminary Recommendation
Rehabilitation
No Action

Sewer Manhole
Sewer Gravity Main
2000 HB PDR Area

Lowell, Massachusetts
Centralville Sewer Separation PDR

Figure 3.7
Preliminary Manhole Recommendations

4.0 Hydraulic Modeling of the Drainage System

4.1 Introduction

Hydraulic modeling of drainage and collection systems helps determine the capacity and pipe sizes necessary to convey wet-weather flow under dynamic conditions. This section describes the development and application of EPA's Stormwater Management Model (SWMM) for design of a stormwater pipe network to support separation of the Humphrey's Brook Basin. The initial network layout was based on the 2000 HB PDR , which included only the main conduit. For this study, the modeled drain network was extended to include the collector drains that are required to capture flow from all existing catch basins.

4.2 Rainfall Design Criteria

4.2.1 General

Rainfall design storms are used to size the stormwater piping system to collect surface water runoff. A range of design storms, based on average recurrence intervals (ARI), may be considered in a study to evaluate the relative cost and benefits achieved by increasing conveyance capacity. Typically, the range of design storms for municipal systems may include 2-year, 5-year, and 10-year ARI storms as evaluation criteria.

4.2.2 Past Evaluation

The 2000 HB PDR used several historical storms to evaluate existing CSS capacity and the proposed stormwater piping network. That study considered several hydraulic and constructability factors, concluding that it was practical to build a new stormwater system with a 5-year design storm capacity. Modeling performed for this PDR reconfirmed that the stormwater system should be constructed for a 5-year storm capacity to convey Humphrey's Brook to the Merrimack River. Larger drain pipe sizes would be required to convey flow generated by a 10-year storm; however, constructability of such large diameter pipes is not feasible for the proposed separation program in this area.

4.2.3 Current Evaluation

For this study, CDM Smith initially assumed preliminary pipe sizes and potential route configurations based on a 5-year 24-hour rainfall hyetograph determined from National Oceanographic and Atmospheric Administration (NOAA) Atlas 14, Volume 10, published in 2015. To consider the impact of a larger storm event, a 10-year 24-hour storm was also simulated for the stormwater system having a 5-year design storm capacity to assess system performance and identify areas that may be susceptible to short-term flooding.

Design storm magnitudes were adjusted to consider future climate change. This study incorporates a 10 percent increase to Atlas 14 depths to account for potential climate change. This increase was estimated based on a 2022 NOAA report "Analysis of Impact of Nonstationary Climate on NOAA Atlas 14 Estimates" [1] which forecasts that 2-year 1-day rainfall in the Northeast will increase by between 6 percent and 11 percent by 2075 relative to Atlas 14 estimates based on Representative Concentration

Pathway (RCP) 4.5 climate model results. **Figure 4.1** shows cumulative depth-duration-frequency curves for 2-, 5-, and 10-year 24-hour design storms adjusted for climate change.

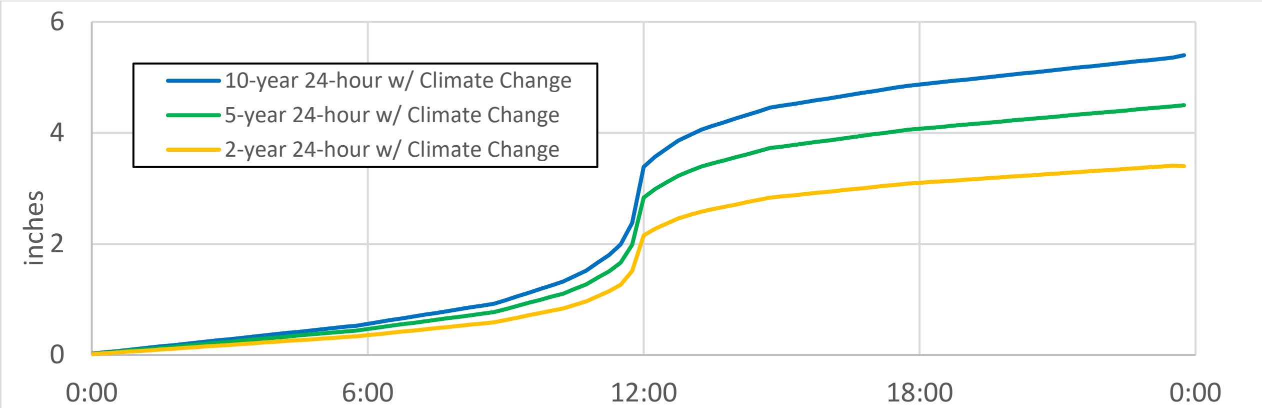


Figure 4.1 Design Storm Cumulative 24-Hour Rainfall

Table 4.1 presents design storm depth maxima at selected durations.

Table 4.1 Design Storm Characteristics

	Maximum Design Storm Rainfall (inches) at Selected Durations		
Interval	**2-Year**	**5-Year**	**10-Year**
15 minutes	0.66	0.86	1.02
1 hour	1.14	1.49	1.78
24 hours	3.45	4.51	5.38

4.3 Drainage Area Delineation and Hydrology

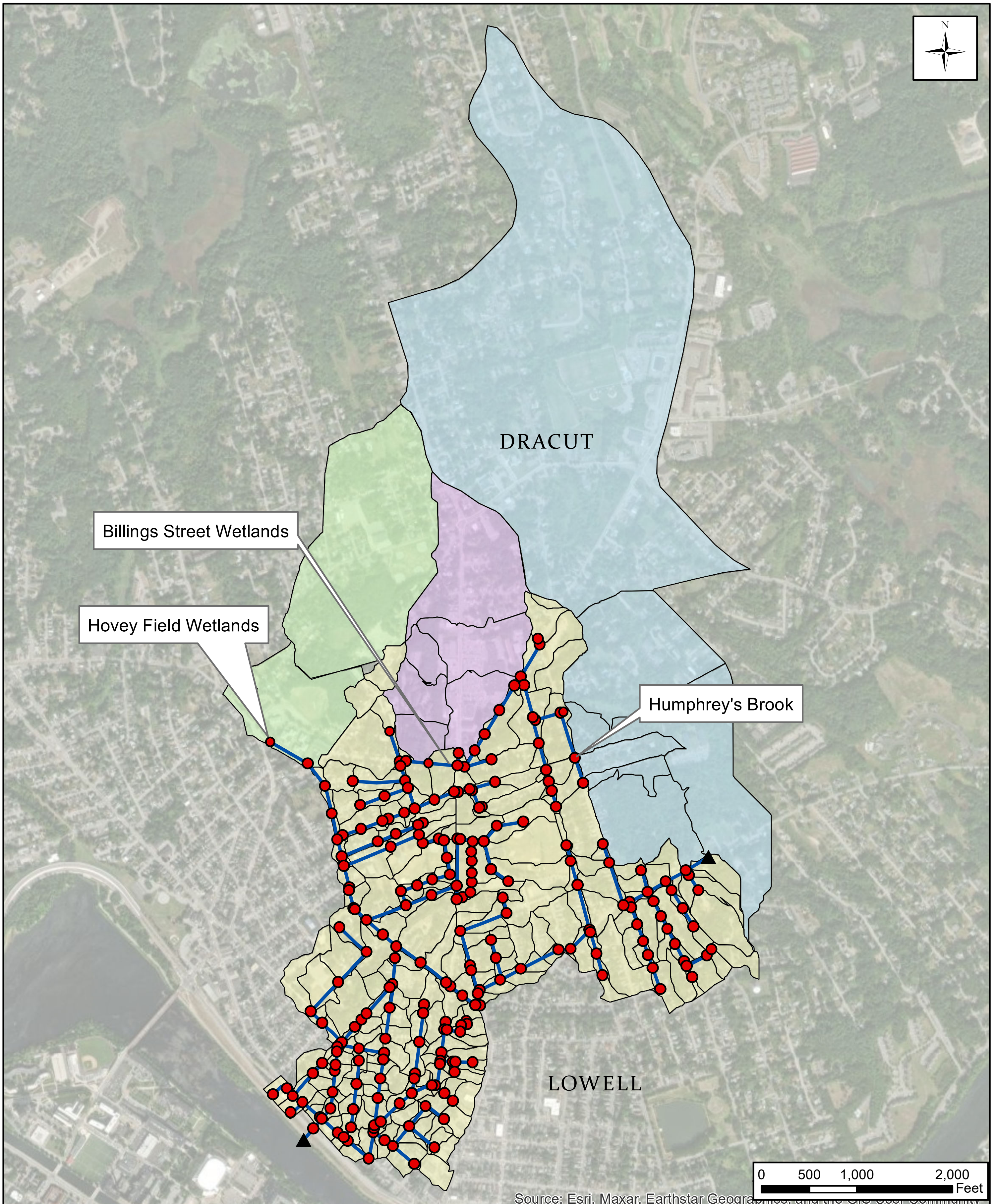
The 2000 HB PDR Area comprises 860 acres in Lowell and Dracut. It includes Humphrey's Brook, wetlands and open channel drainage north of Billings Street, Hovey Field Wetlands, and surface runoff from Lowell. As discussed in Section 2, the primary surface water inflow sources are Humphrey's Brook, which drains into Lowell from the east, and the Billings Street Wetlands and Hovey Field Wetlands, which lie near the northern city boundary. The model uses the NAVD 88 vertical datum (feet) and the Massachusetts Mainland coordinate system (feet, NAD 83).

As an initial criterion for SWMM pipe simulations, minimum pipe cover was established at 4 feet below existing ground surface. Pipe slopes and inverts will be adjusted during the design process based on utility conflicts, alternate routing, and topography. The final configuration of the drain system will be re-simulated to ensure conformance with the design standards for conveyance piping such as minimal cover, minimum or maximum slopes, pipe sizing to minimize surcharging, etc. Drain manholes (model junctions) were added near existing catch basins so that these basins can be re-routed from the existing combined sewer system. Changes in pipe diameter were configured to match downstream crowns where feasible. Vertical drops were applied to maintain an acceptable range of slopes and pipe velocities based on pipe size. Pipe slopes and sizes will be revised to resolve utility conflicts as the system design progresses.

Drainage from Dracut via the brook and wetlands was based on subcatchments originally delineated in the 2014 CSO Phase 2 Long-Term Control Plan and refined for this study through additional review. Detailed subcatchment delineation was performed for areas within Lowell to best represent surface runoff within the study area. As part of this process, drainage areas were delineated using 1-foot contours and adjustments were made to the subcatchments to account for roads and streets. Average subcatchment size within Lowell is 1.5 acres. **Figure 4.2** shows the drainage area delineations. The aerial photogrammetry background has been added to the figure to show the relative density of development differences between Lowell and Dracut.

Hydrologic parameters were assigned based on local data and best engineering practices. Initial hydrologic parameters for the SWMM model were developed as described below:

- Imperviousness was calculated from Massachusetts Impervious Surface 2016 data obtained directly from MassGIS [2]. Imperviousness averages 40 percent across the study area.
- Percent routed identifies the fraction of a subcatchment impervious surface that drains onto adjacent pervious ground (e. g., roof leaders that drain to bare ground). Percent routed was specified as 100% minus percent imperviousness, yielding effective imperviousness equal to the square of total imperviousness. For example, a subcatchment with 75 percent imperviousness would be specified with a 25 percent routing coefficient, yielding 56 percent effective imperviousness.
- Average surface slope for each subcatchment was calculated using a digital elevation model developed from the contours.
- Manning’s N was specified as 0.02 for impervious surfaces and 0.08 for pervious ground.
- Subcatchment width (the hydrograph shape parameter) was based on the Guo and Urbonas method recommended in the SWMM hydrology manual using a skew factor of 0.5, an upper limit shape factor of 5, and calculated lengths using the “minimum bounding geometry” tool in ArcGIS Pro [3].



Legend

- Model Junctions
- Model Conduits
- Model Outfalls
- Humphrey's Brook
- Billings Street Wetlands
- Hovey Field Wetlands
- Lowell Separation

Lowell, Massachusetts
Centralville Sewer Separation PDR

Figure 4.2
Drainage Area Delineation

- Infiltration from pervious areas is modeled using the modified Horton method. The principal soil type in the study area is sandy loam, according to the US NRCS Web Soil Survey [4]. Soil parameters were uniformly specified as 2 inches per hour maximum infiltration rate and 1 inch per hour minimum infiltration rate.

Hydrologic parameters for the area draining to the Humphrey's Brook inlet structure at Humphrey Street were calibrated to continuous flow metering data obtained from the Utility's permanent meter for February to August 2023. Calibrated values for percent routed and subcatchment width parameters developed for the Humphrey's Brook tributary area, based on this flow meter, were transposed to the Hovey Field Wetlands and Billings Street Wetlands subcatchments.

Figure 4.3 compares observed and simulated peak flows for 10 storms at the Humphrey's Brook inlet. Rainfall data obtained from the Utility's gauge at the Warren CSO Station was used to simulate streamflow as it had more representative spring data for the drainage model. Figure 4.3 shows minimal overall bias between modeled and observed peaks, validating the model's configuration. Peak flow for individual storms is not strongly correlated with measured peaks due to the two-mile distance between the rain gauge and the watershed centroid.

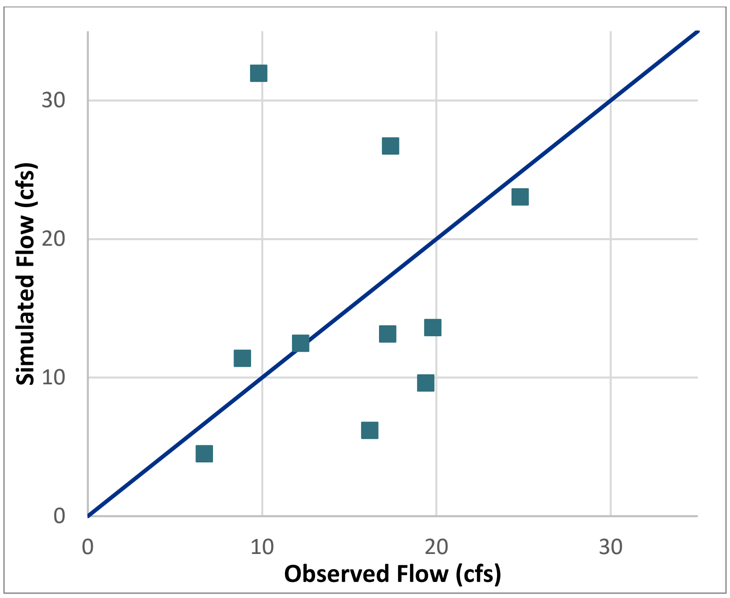


Figure 4.3 Observed and Simulated Peak Flows for Humphrey's Brook

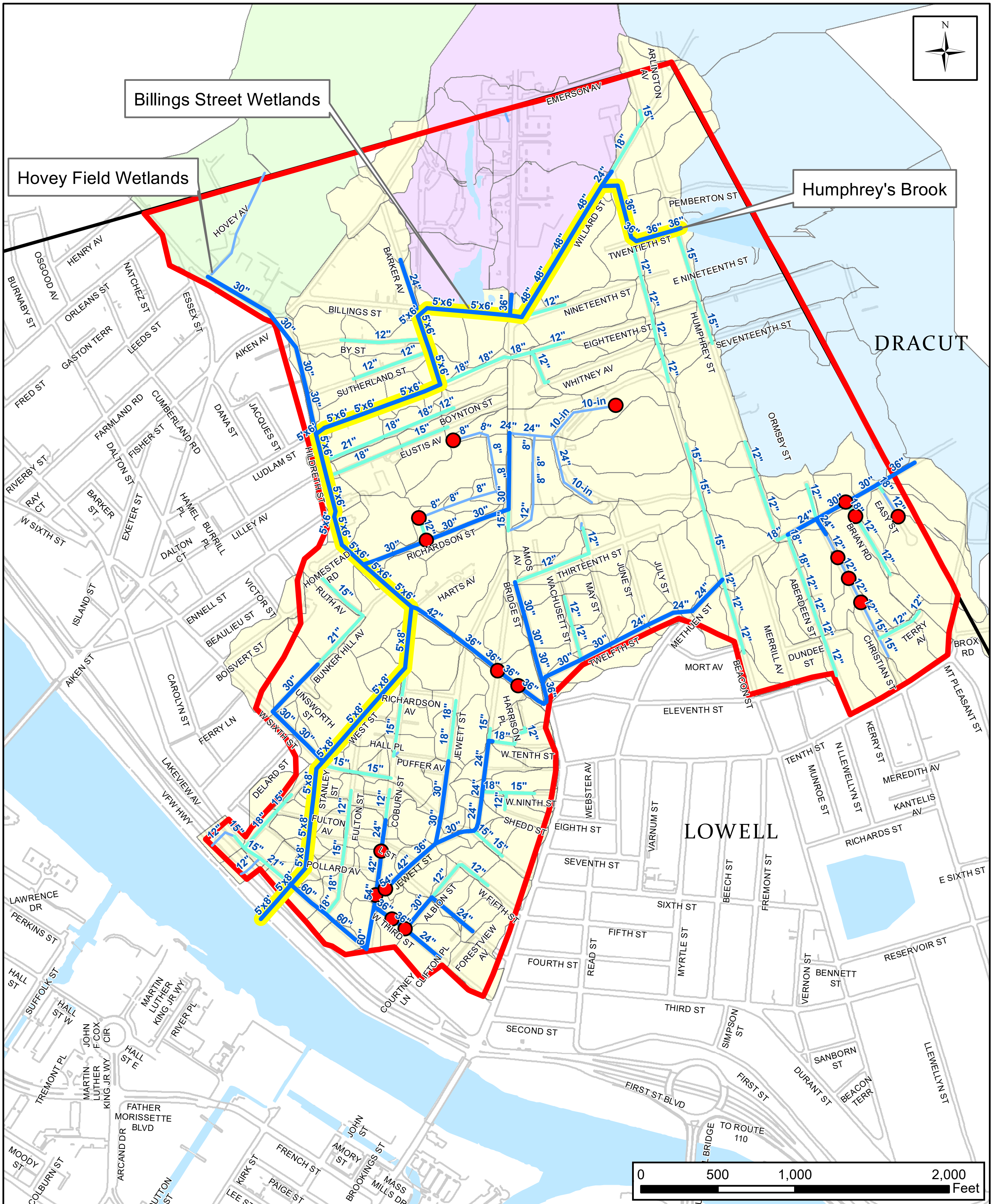
The average routing coefficient for subcatchments tributary to the Humphrey's Brook flow meter was adjusted from an initial value of 75 percent to 8 percent and the subcatchment width was also adjusted to account for observed flow dampening effect of the brook and its upstream wetlands.

4.4 Conceptual Hydraulic Analysis

SWMM was used to identify pipe sizes that would minimize surcharge above pipe crowns during a 5-year design storm. The 10-year storm was then run to identify excessive surcharge and street flooding duration. Flooding was defined as any location that experiences more than 15 minutes of flooding and 2,000 gallons of ponded volume. No locations had any significant flooding under this criterion with the simulation of a 10-year storm except for areas with existing drain pipes (suggesting they are slightly undersized) and a low lying area of concern that will be discussed further in Section 6 Development of Alternatives.

Figure 4-4 shows the modeled pipes, a conceptual pipe route, and initial sizes for a stormwater collection system designed for the 5-year storm. The main conduit follows the route proposed in the 2000 HB PDR, discharging to the Merrimack River across from Stanley Street. This is a comparative analysis to the 2000 HB PDR to see pipe size changes after applying the current design storm criteria.

Initial hydraulic simulations indicate that the size of the main conduit for the required brook removal and future combined sewer separation in Lowell varies from 36- to 48-inch diameter at the upstream limit (an existing 36-inch diameter pipe connects the brook to the drain system) to a 5-foot high by 6-foot wide box culvert downstream of Billings Street Wetlands that transitions to a 5-foot high by 8-foot wide box culvert near the downstream end. These results are consistent with the 2000 HB PDR analysis although pipe diameter lengths vary along the route. Additionally, the size of the box culvert south of Hildreth Street continued as a 5-foot by 8-foot dimension to mitigate surcharge along this segment and near the West Station where the conveyance system transitions from steep to flatter pipe slopes to match the existing topography.



Legend

- Main Conduit
- Drain (24" and Greater)
- Drain (18" or Less)
- Existing Drain
- 2000 HB PDR Area
- 10-Year Storm Flooding

Subcatchments

- Humphrey's Brook
- Billings Street Wetlands
- Hovey Field Wetlands
- Lowell Separation

CDM Smith

Duck Island — Lowell Regional Wastewater Utility

Lowell, Massachusetts
Centralville Sewer Separation PDR

Figure 4.4

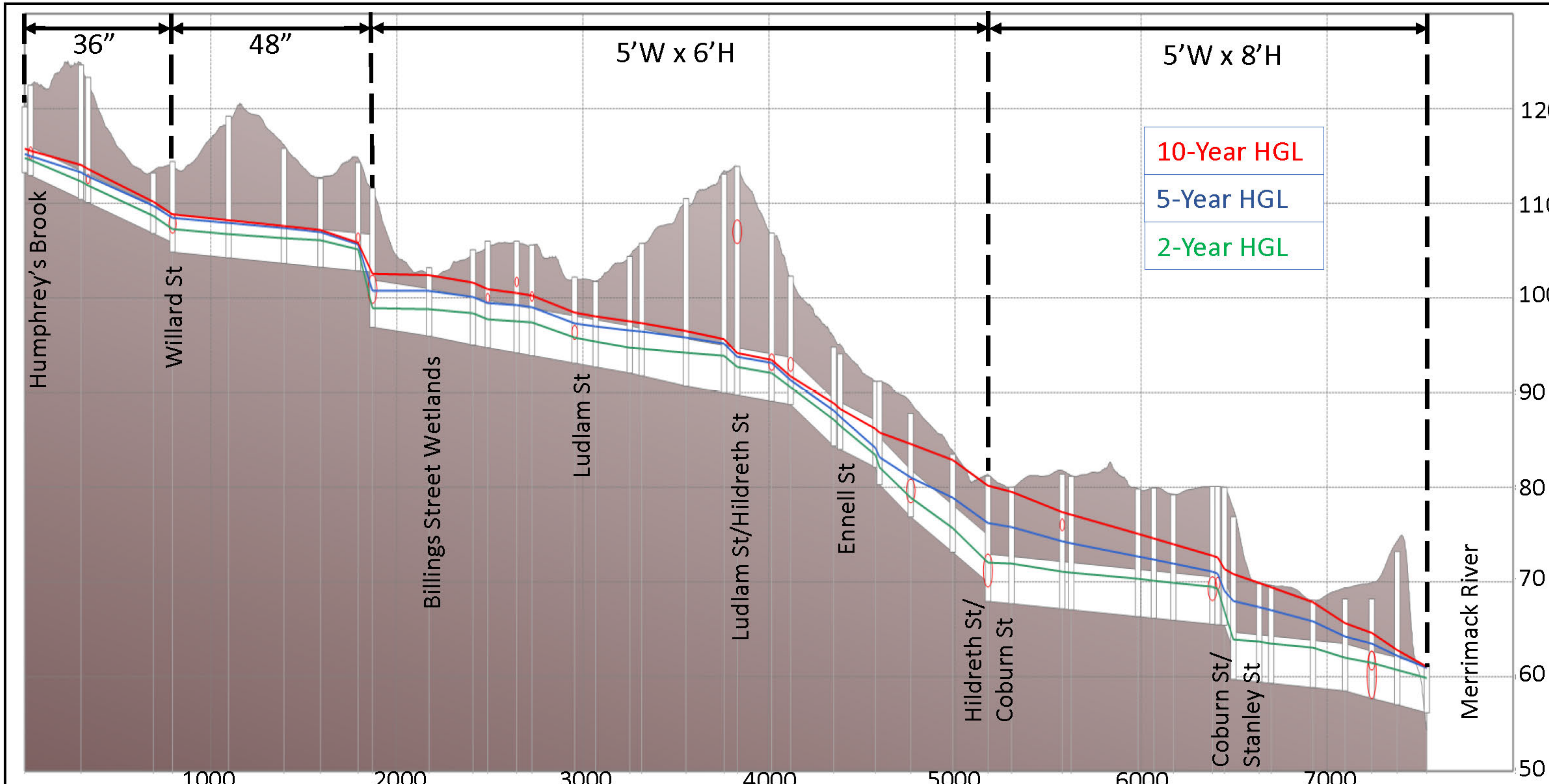
Conceptual Drainage Network

Figure 4.5 shows the peak hydraulic grade line (HGL) in the main conduit for the 2-year, 5-year, and 10-year storms from the Humphrey's Brook inlet to the outfall. Figure 4.5 shows surcharge in downstream sections during the 5-year storm (blue line), but no flooding along the main conduit. The 10-year HGL (red line) exhibits minor flooding in low-lying areas. Flooding during the 5-year storm does occur in undersized existing drains near McPherson Playground, Gage Park, and Christian Street. Locations subject to flooding in are indicated in Figure 4.4.

Table 4.2 shows peak flowrates at key locations along the main conduit for each design storm to show the magnitude impacts of inflow sources and separation.

Table 4.2 Peak Flowrates at Key Locations along Main Conduit

Design Storm Peak Flows (cfs)			
Location	**2-year**	**5-year**	**10-year**
Humphrey's Brook Inlet	28	41	53
Downstream of Billings Street Wetlands	99	156	179
Hildreth Street & Coburn Street Intersection	194	303	353
Outfall	367	545	633



CDM Smith

Lowell, Massachusetts
Centralville Sewer Separation PDR
Figure 4.5
Peak Hydraulic Grade Line Profile for 2-,5-,10-year 24-hr Design Storm

4.5 Drainage Modeling Next Steps

The large size of the main conduit required to remove the brook and other Dracut inflow sources creates significant construction challenges. The large conduit could conflict with other underground utilities, requiring relocation, or with existing sewer services, requiring new parallel services. Fitting the drain into narrow streets near West Station would require reconstruction of entire roadways following pipe installation.

Section 5 discusses the general construction challenges created by this type of pipe installation. Section 6 identifies and discusses alternative approaches to reduce pipe size or identify alternative pipe alignments to reduce construction impacts. These alternatives also used SWMM to evaluate pipe size benefits and flow routing. A comprehensive hydraulic assessment will be performed during final design on the proposed alignment and configuration of the drainage system.

4.6 References

[1.] Office of Water Prediction. Analysis of Impact of Nonstationary Climate on NOAA Atlas 14 Estimates. National Weather Service, Silver Spring, Maryland, 2022. Retrieved from https://hdsc.nws.noaa.gov/pub/hdsc/data/papers/NA14_Assessment_report_202201v1.pdf

[2.] Bureau of Geographic Information (MassGIS). Commonwealth of Massachusetts, Executive Office of Technology and Security Services. Massachusetts Impervious Surface 2016. Accessible at https://hub.arcgis.com/maps/1b2efe6d7b144fcf82376692d3de304b/explore?location=42.369743%2C-71.057361%2C13.73

[3.] Rossman, L. AND W. Huber. Storm Water Management Model Reference Manual Volume I, Hydrology. U.S. EPA Office of Research and Development, Washington, DC, EPA/600/R-15/162A, 2015. Retrieved from https://nepis.epa.gov/Exe/ZyPDF.cgi/P100NYRA.PDF?Dockey=P100NYRA.PDF

[4.] Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Web Soil Survey. Accessible at https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

5.0 Potential Construction Challenges

5.1 Introduction

Potential construction issues and environmental impacts that may be encountered during the installation of new drains or sewers should be considered as part of the design process. This type of work becomes more challenging when pipe diameters exceed 36-inches due to potential conflicts with other underground utilities. In addition, consideration should be given to construction challenges such as disruptions to property and pedestrian access, impacts to traffic flow, local impacts such as noise and dust, and wetland and permitting issues (driven by the wetland impacts and land ownership).

While there will be short-term negative impacts during construction, many of these impacts can be reduced by implementing various mitigation measures. The selection of pipe routes, depths, sizes, and configurations is often driven by approaches to avoid or mitigate such impacts. These are discussed further during the alternative development and analysis presented in Section 6.

5.2 General Construction Impacts

5.2.1 Underground Utility Conflicts

Underground utility conflicts represent a challenge for pipeline projects. Construction near adjacent utilities needs to consider the installation method to avoid undermining an existing adjacent utility if it is bedded higher than the new pipe. The preferred installation method usually is a function of the type of trench support used, which can mitigate the impact on existing utilities. In addition, pipe trenches must be dewatered to install the pipe in dry bedding material so that there is no differential settlement. Dewatering for the pipe installation must be carefully planned to avoid excessive dewatering of nearby utilities that could create differential settling within the street.

Depending on the depth of the new sewer or drain, utility conflicts can also increase. If a new sewer is installed, it will likely be lower than the existing sewer to reconnect existing property sewer services. This means that the new sewer will be deeper than any of the adjacent sewers; therefore, construction and associated vibration can impact the surrounding utilities and properties. Vibration monitoring may be required for older utilities.

Drains may be installed more shallow. However, the drain inverts may still be below other existing utilities such as water mains, gas, telephone, and electric utilities. Large shallow drains may also block the reconnection of existing sewer services to the sewer pipe, creating the need for new parallel sewers.

Finally, new drains may have to be installed within the profile of existing sewer pipe, which can “block” the advance of the drain. Then either the drain or the sewer profile needs to be modified to resolve the conflict but the ability to change the sewer profile might be limited because the sewer generally must connect to a downstream fixed connection point. As a result, each situation requires an evaluation to determine which utility to move.

These issues will be considered in the final design process when pipe routing, connectivity, and pipe inverts are established in final plan and profiles.

5.2.2 Traffic Management and Pedestrian Access

Maintenance of traffic and property access along the construction zone is a high priority for this project.

A significant portion of the work in the Humphrey's Brook Basin will take place in dense and highly congested residential, multifamily, and commercial areas. There are several thoroughfares through the Centralville neighborhood that are the main transportation corridors. These main transportation corridors include Hildreth Street, Bridge Street, Methuen Street, Aiken Avenue, Willard, and Lakeview Avenue, along with work adjacent to and across VFW Highway, a state roadway (for the construction of the outfall pipe(s)). Traffic management issues to be considered include at a minimum access for emergency vehicles, minimizing disturbance to local businesses, safety of school children, and access to residences along the affected routes. Some of these concerns can be addressed during project preliminary design by avoiding sensitive areas such as schools, medical centers, and places of worship, if feasible. If these areas cannot be avoided during the design, then appropriate mitigation must be developed and implemented during final design to minimize the impact.

Typical traffic mitigation measures include the following:

- Advance signage
- Parking restrictions
- Relocating bus stops or bus routes, including integration with the Lowell Regional Transit Authority, Senior Transportation, and School Department
- Shifting travel lanes
- Lane reductions
- Limited access and detours

Mitigation measures should consider the implications that work zones have for abutters in terms of construction time of day, driveway locations, detour suggestions, and noise, and will also consider pedestrian access with proper signage. Locations of displaced parking will be identified and coordinated with the City. The public will be engaged to reduce impacts to daily life to the best extent possible.

Many of these traffic and pedestrian measures are generally addressed in the preliminary and final design. More detail will be required in the traffic management plan prepared by the construction contractor, which will be subject to review and approval by several City departments including the Lowell Police Department, Fire Department, Department of Planning and Development – Traffic Engineer, and City Engineering.

The traffic management plan will address road closings, signage, traffic patterns, bus routes, and traffic light timing adjustments and should incorporate the following elements:

- Provide access to all buildings, businesses, and parking areas. Provide specific signs to affected businesses when normal access is modified.
- Maintain one lane of traffic on all major routes at all times to the best extent possible. However, it should be acknowledged that, for the installation of large diameter pipes and/or under certain

construction conditions, maintenance of even one lane of traffic may be infeasible and detours will have to be adopted. To the extent possible, this will be avoided along the major access streets.

- Identify vehicular and pedestrian traffic patterns around schools, playgrounds, and any other "pedestrian sensitive" areas.
- Develop detailed traffic and detour planning.
- Provide advance and robust notification and signage of all traffic detours due to construction as approved by other City departments.
- Use police details where required at all active work zone locations.

Each street will be analyzed to determine the best method to provide access to all entrances. At times, snow fencing will be utilized to direct traffic flow. Advance planning and phasing of construction on each street to address issues related to traffic will minimize disturbances to affected businesses and residents.

5.2.3 Noise

Potential noise impacts are evaluated based on the proximity of construction activities to sensitive land uses and receptors including businesses, residences, schools, medical centers, places of worship, and recreational sites. A majority of the area selected for sewer separation is residential, which is more sensitive to noise impairments than industrial or commercial areas. There will be a noticeable increase in noise during construction; blasting of ledge or rock also will have a significant impact on noise levels. To mitigate noise impacts, the following measures are recommended:

- Use new or well-maintained equipment with standard intake/exhaust mufflers and engine jackets. The best available noise-reducing technology, such as specialized mufflers and shields, could be necessary to reduce impacts at some locations. Decibel level restrictions could be added to the design documents in very sensitive areas as long as these safeguards are practical and would not significantly increase construction costs, unless warranted.
- Use the most quiet and practical construction techniques, such as replacing standard pile drivers, if needed, with vibratory or sonic drivers, to eliminate noise from the hammer hitting the pile.
- Restrict construction activities to daytime hours and/or schedule noisier activities to take place during less sensitive times of day.
- Surround loud equipment such as generators with straw bales or plywood to reduce impacts of sound on the neighborhood.

5.2.4 Blasting

Based on a review of past construction records, there will be significant areas of the project that require rock excavation to install the pipe (based on visible ledge outcrops seen throughout the project area, and available boring logs from the ongoing boring program for this study).

Rock may be excavated by numerous techniques including drilling, blasting, wedging, sledging, or barring. Prior to the start of rock excavation or blasting work, a pre-blast survey of all existing structures and conditions in the vicinity of the work area will be conducted by the contractor. This survey will include videotaping each building's exterior to establish preconstruction conditions.

Vibration monitoring will be required during all blasting activities. A blasting plan, describing proposed methods and sequence of excavation, including blasting procedures, will be developed to address the specifications. Blasting will be limited to business hours, Monday through Friday, unless prior permission is received from the Lowell Fire Department. An adequate warning system will be provided to ensure that all persons are at a safe distance before a blast is detonated. Blasting signals will be required to conform to 29 CRR 1926.909 (OSHA) and posted.

All blasting will be in compliance with state, federal and OSHA Health and Safety Standards for Construction. Persons responsible for blasting will be licensed blasters in the Commonwealth of Massachusetts and will be required to have acceptable experience in similar excavations in rock and controlled blasting techniques. Prior to blasting, a blasting permit will be obtained from the Chief of the Fire Department.

5.2.5 Fugitive Dust

Construction activities such as excavation, grading, backfilling, and hauling can generate airborne dust. Particulate matter (PM) less than 10 micrometers in aerodynamic diameter (PM-I0) has the potential to be a health hazard as well as a nuisance. Tests conducted for the U.S. EPA concluded that the dominant source of construction PM-10 emissions is not passive wind erosion, but movement of heavy vehicles over unpaved surfaces or construction excavation activities. These emissions are a function of vehicle activity, weights, speeds, number of wheels, soil silt, and moisture content [1].

Construction activities such as excavation, scraping, and jack hammering also will generate airborne dust. Fugitive dust mitigation measures will be required since some residences and sensitive receptors will be within 50 feet of construction. However, impacts will be temporary and can be controlled with mitigation measures such as regular watering of active construction areas, street sweeping, covering trucks carrying earth material, and clean-up of spillage on paved and unpaved travel surfaces. These mitigation measures should reduce fugitive dust impacts to an acceptable level.

5.2.6 Schools, Parks/Playgrounds, and Sensitive Receptors

There are several schools, playgrounds, and public parks that are adjacent to streets that will be impacted by construction, including the S. Christa MaAuliffe Elementary, Henry J. Robinson Middle, and Greenhalge Elementary Schools, along with McPherson Park/Pool and Hovey Field. Schools require a significant level of coordination, especially during the school year, to minimize pedestrian impacts and facilitate bus transportation for the students. The contract documents may identify special conditions such as limiting allowable times of construction to non-school hours (or, if feasible, the summer), maintaining access to school, coordinating with school bus schedules, noise and dust control, safety requirements and final restoration. Additionally, the contract documents will address traffic control and access requirements for construction in abutting streets around the school, especially for students that walk to school.

Construction of new stormwater drains may also occur in the vicinity of McPherson Park and Hovey Field. McPherson Park includes a playground, three softball fields, tennis courts, basketball courts, and a pool. Prior to construction, coordination with the City's Department of Public Works and Parks Department will occur and access constraints during construction to McPherson Park and Hovey Field will be minimized.

Other sensitive receptors in the Centralville neighborhood include daycare and nursery centers, churches, medical, and local businesses. During final design and construction, there will be frequent communications with these entities and the City's Department of Planning and Development Neighborhood Outreach Coordinator to make sure that access is maintained and detours accommodate the use of these facilities.

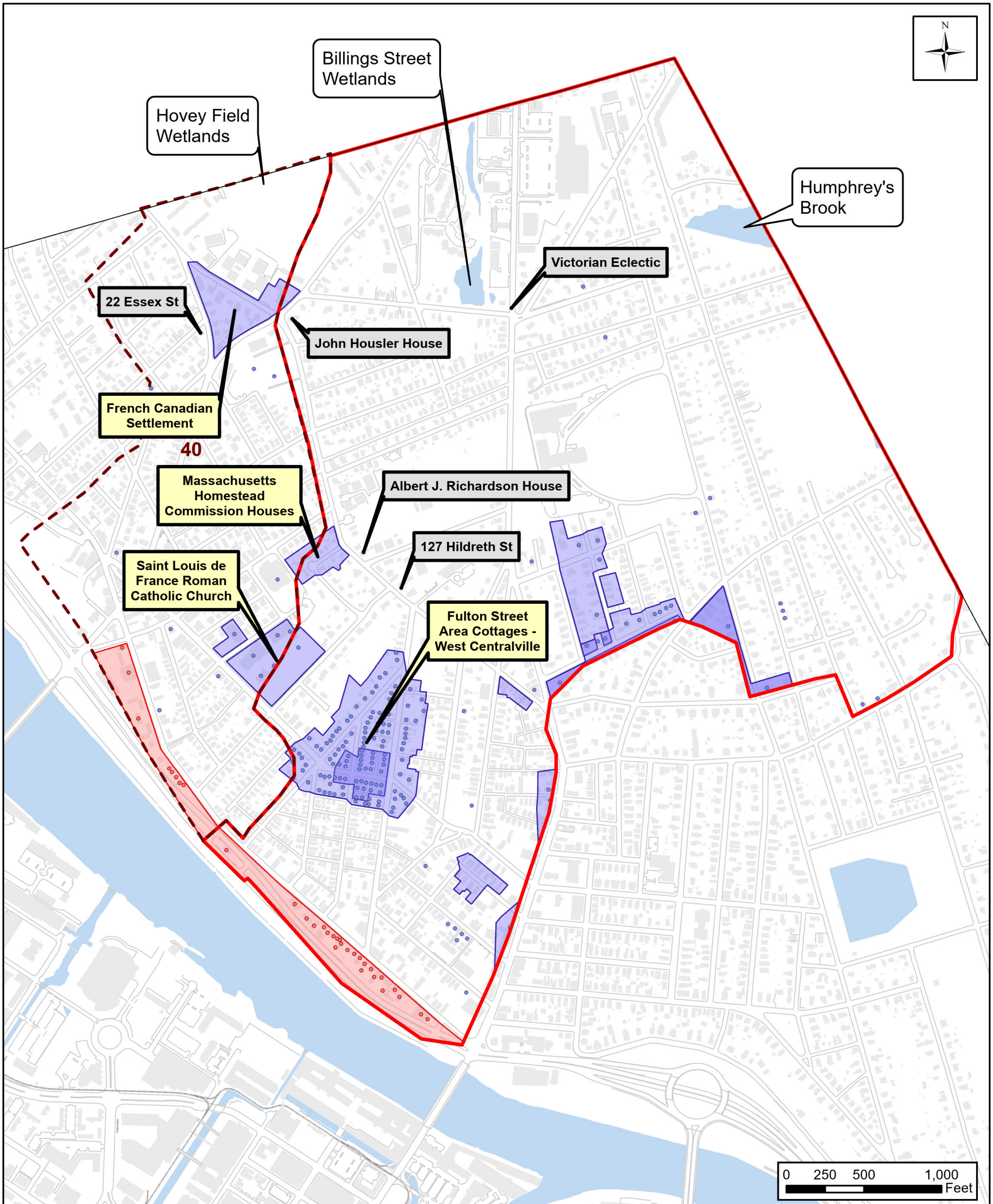
5.3 Environmental and Project Area Permitting

While not a direct construction impact, extensive permitting activities are needed to notify all appropriate federal, state, and local agencies about the project and its impacts and to comply with applicable regulations. Permitting can be extensive for a construction project of this size and complexity. The permitting activities include an accounting of historic and archaeological resources, wetland and water body impacts, and excess soil disposal characterization and disposal.

5.3.1 Historic and Archaeological Resources

Historical and archaeological resources should be identified before the start of construction either through database research and/or coordination with the Massachusetts Historical Commission (MHC). This effort is typically done during the final design process when the immediate construction area is well defined. As a start, CDM Smith consulted with the National Registry (NRDIS designated 1978) and identified some areas of historical or archaeological significance, as shown on **Figure 5.1**, including:

- Local Historical Districts (these include areas or groupings of inventoried points):
  - French Canadian Settlement (MHC ID: LOW AB). Residential District. Significance: Architecture, community planning, and ethnic heritage
  - Massachusetts Homestead Commission Houses (MHC ID: LOW.AE). Significance: Architecture, community planning, landscape, architecture, social history
  - Saint Louis de France Roman Catholic Church (LOW.CR). Significance: Architecture, community planning, and ethnic heritage, and religion
  - Fulton Street Area Cottages – W. Centralville. Residential District. Significance: Architecture, community planning, and Agriculture
- Individual Inventoried Points:
  - 1104 Bridge Street, MHC ID: LOW.742) (Victorian Eclectic)
  - John Housler House at 321 Hildreth Street (MHC ID LOW.771)
  - Albert J. Richardson House at 61 Hildreth Street (MHC IC: LOW.769)



Legend

MHC Inventory Points
- Inventoried Property
- National Register Historic (NRH) Places

MHC Inventory Areas
- Inventoried Area
- National Register Historic (NRH) Places

- Sewer Area 40
- 2000 HB PDR Area

Lowell, Massachusetts
Centralville Sewer
Separation PDR

Figure 5.1
Historical Districts and Locations

- 22 Essex St (LOW.745) (single family dwelling)
- 127 Hildreth Street (LOW.770) (single family dwelling)

The project will not result in the destruction of any historical structures. Most of the work under this project will occur within streets or at existing structures (i.e., areas that have already been disturbed) so impacts to archaeological resources are not anticipated.

5.3.2 Wetlands and Water Bodies

Wetlands are classified along every water body in the state and the work required for this project may impact these areas. Stream brook inlets to the drain system will require new inlet structures and piping, which may result in the following impacts:

- Areas of Bordering Vegetated Wetland (BVW) and Land Under Water (LUW) could be impacted by the installation of new piping or structures to connect the Humphrey's Brook inlet at Humphrey's Street to the new drain system. The area impacted by the work may be limited to the extent of the new headwall including wingwalls and riprap.
- Another area of BVW, dominated by Phragmites australis, will be impacted by the removal of the existing inlet structure at Billings Street Wetland and the construction of a new structure. The existing sediment level in this area will be maintained and impact to the wetlands will be limited to the area immediately surrounding the existing inlet structure.

The new stormwater drain facilities will also require outfalls. Work at these outfalls could impact local wetlands as follows:

- Under the proposed Centralville CSS plan, stormwater flows that currently drain to the combined sewer in Methuen Street will be discharged at an existing outlet near Easy Street. This additional flow will have a limited impact on BVW in the vicinity of the outlet. The existing headwall at this location may need to be replaced to accommodate a new drain system and increased flows. Local BVW and the stream bed near the existing outlet may be temporarily impacted during construction of the new headwall and wing walls. Substantial riprap could be provided in this area to help minimize potential impacts of the increased discharge.
- Direct impacts to the Merrimack River may occur at potential new outfalls at Aiken Street, Bunker Hill Avenue, and Stanley Avenue.

Measures to mitigate temporary impacts to wetland resource areas include sedimentation controls (e.g., silt fence and straw bales and/or compost sock on land, silt curtains, coffer dams, sheeting in water) to prevent siltation of down gradient wetlands or water bodies, and restoration of disturbed areas to the extent feasible (restoring existing contours and re-seeding with native seed mixtures as needed). Any work that occurs outside the street right-of-way and within 100 feet of wetlands will require a Notice of Intent (NOI) or a Request for Determination of Applicability (RDA). However, it is our understanding that installation of underground utilities within existing streets is exempt from review by the Lowell Conservation Commission per 310 CMR 10.02(b)2.i., to be confirmed during the final design phase.

Some of the new pipe alignment will also occur within the Riverfront Area, a state wetland resource area that typically extends 200 feet from the mean annual high-water line on each side of a perennial river or stream. However, the Riverfront Area is 25 feet in some municipalities in Massachusetts including Lowell. Since most of the work in the Riverfront Area will be in existing streets, the impact is expected to be small. Intermittent streams do not include a Riverfront Area. Similar to installation of underground utilities within existing streets, there is an exemption for minor activities within Riverfront Areas per 310 CMR 10.02(a)(1).

Any temporary or permanent impacts to wetlands will require approval by several regulatory authorities including the Lowell Conservation Commission, Massachusetts Department of Environmental Protection (MassDEP), Division of Wetlands and Waterways (401 Water Quality Certification and Chapter 91 License), the Massachusetts Office of Coastal Zone Management, and the U.S. Army Corps of Engineers.

5.3.3 Wetland and Access Permits

Permits required to construct the Humphrey's Brook sewer separation project may include the following:

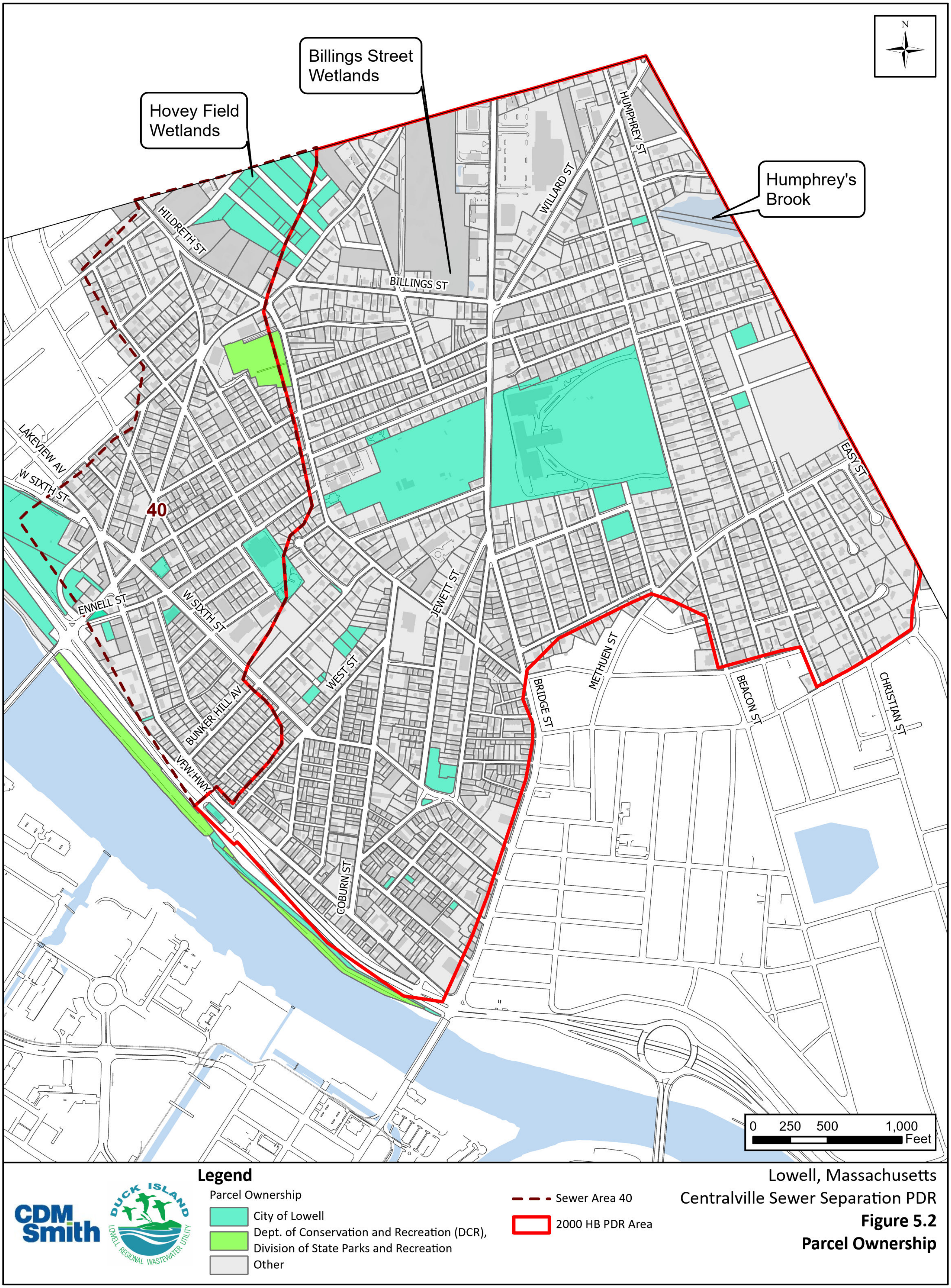
- Written notification to the Lowell Conservation Commission for geotechnical borings within the 100-ft Buffer Zone and Riverfront Area. If geotechnical borings need to be collected from wetland resource areas (i.e., Land Under Water, Inland Bank, or Bordering Vegetated Wetlands) then a Notice of Intent would need to be filed with the Lowell Conservation Commission for approval.
- Order of Conditions (OOC) from the Lowell Conservation Commission for any temporary impacts to Inland Bank, BVW and LUW for the construction of new inlet structures and for a new outlet to the Merrimack River. Less than 5,000 square feet of BVW and LUW is expected to be temporarily impacted by construction activities and therefore the OOC serves as the 401 Water Quality Certification.
- Self-Verification (SV) under the Massachusetts U.S. Army Corps of Engineers General Permit (GP) 6 (effective June 2, 2023) for any temporary <5,000 square feet of alteration to Humphrey Brook and/or vegetated wetlands regulated as Waters of the U.S.
- Massachusetts Environmental Policy Act (MEPA) review. A pre-application meeting with MEPA staff will be scheduled for guidance if a new Environmental Notification Form (ENF) or Notice of Project Change (NPC) should be filed. Earlier phases of the CSO Consent Decree were reviewed by MEPA under EEA file Number 12059.
- Massachusetts Highway Department Access Permit for work in VFW Highway right-of-way.
- Coordination with MHC and Project Notification Form (PNF) Submittal.
- The MHC is the state agency which functions as the State Historical Preservation Office in Massachusetts and identifies, evaluates, and protects the state's significant cultural resources under Section 106 of the National Historic Preservation Act (NHPA). Compliance with Section 106 and/or M.G.L Chapter 9, Sections 26-27c, as amended by Chapter 254 if the Acts of 1988 (950 CMR 71.00) is required for projects with any state action (which includes SRF funding).

  Since the proposed project is mainly located within existing streets and in previously disturbed areas, it is not anticipated that any inventoried historical resources or archeological resources would be impacted. A Project Notification Form (PNF) will be submitted to MHC to initiate the consultation process and their review of potential impacts to significant historical and archeological resources.

The PNF would include a detailed narrative description of the proposed project; a description of the existing conditions and the nature of any past development of disturbances on the project site, if any; a list of all the federal and state funds, licenses, and permits required for the project; photographs of existing areas to be disturbed; and a USGS project location map and proposed site plan.

In addition to the wetland and access permits required above, a new drain outfall to the Merrimack River may require the following additional permits/approvals (if the Aiken Street outfall is installed in the non-flood protection portion of the river bank, the Pre-Construction Notification and the Section 408 application/permit may not be required):

- Chapter 91 License from MassDEP Waterways for construction of a new structure below the ordinary high water mark of the river.
- Article 97 Conversion (Change in Use) petition to the Legislature will likely be required for a new utility easement on Department of Conservation and Recreation (DCR) land (i.e., the Merrimack River bike path) protected in perpetuity as public conservation land. An Article 97 change in use petition is also subject to approval under the 2022 Public Lands Preservation Act (PLPA) which was established by statute and includes a process for submission to the Legislature of petitions to authorize the use of Article 97 land for another purpose. The PLPA is administered by the Executive Office of Energy and Environmental Affairs (EEA) and requires an alternatives analysis for the petition and placement of land, comparable in location and of equal or greater natural resource value, in a conservation Article 97 restriction. Land ownership in the study area is included in **Figure 5.2**.
- Pre-Construction Notification under the Massachusetts USACE GP 6 (effective June 2023). Upper federal jurisdictional limit is the ordinary high-water elevation.
- Section 408 approval from the USACE for permission to install new drain pipe through a Civil Works project (i.e., the Lakeview Flood Protection Project Earthen Levee). The Lakeview Levee is part of the Lowell Local Protection Project and extends from the Bridge Street bridge upstream along the northern riverbank of the Merrimack River up to Aiken bridge. Section 408 allows the USACE the ability to grant permission for another party to alter a Civil Works project upon determination that the alteration proposed will not be injurious to the public interest and will not impair the usefulness or purpose of the Civil Works project. The USACE will review structural design, stormwater design, hydrological and hydraulic design, and compliance with the National Environmental Policy Act (NEPA). A pre-application meeting with the USACE Section 408 Program is recommended. Obtaining approval from the USACE for this particular modification to the Lowell Flood Protection Plan should avoid recertification of the use of the levee for flood protection to properties behind the levee.



Lowell, Massachusetts
Centralville Sewer Separation PDR
Figure 5.2
Parcel Ownership

In addition to the permits listed above, the contractor will be responsible for obtaining any other local approvals needed for pipe installation including but not limited to NPDES Construction GP from the U.S. EPA and Street Opening Permit from City of Lowell.

5.3.4 Soil Disposal and Hazardous Waste

During construction, the project will require excavation of soils, mostly in the street. The soils will be stockpiled, and then backfilled into the excavation and compacted before the final pavement is put into place. During design, typically, an initial investigation to identify known areas of contamination and to anticipate potential hazardous soil conditions along the route will be completed. In addition, surplus soils/spoils are created as the new pipe fills the trench area. These soils must eventually be characterized through environmental sampling to identify final off-site disposal. This soil disposal characterization can either be done before construction begins or when final disposal must be arranged for the surplus materials.

As an initial step, the MassDEP Massachusetts Contingency Plan (MCP) website was consulted to identify the status of all potential and confirmed contaminated sites in the project area. When a site is found to be contaminated and reported to MassDEP, the site is assigned with a unique identifying number that is used to track the site in agency databases. These are called Regional Tracking Numbers (RTNs). There are 11 sites with assigned RTNs listed within 400 ft of the proposed pipe alignments. Of the 11 sites, only one is considered open:

- The Grand Manor Condo Association at the Northern extent of the project area is associated with the open RTN (3-0029226) and two of the closed RTNs (3-0028606 and 3-0028472). This site was assigned an RTN due to the identification of solid waste during excavation related to the installation of new utilities in 2008. Some impacted soil has been removed from the site; however, the use of air purification units within the condominium buildings, due to the concern of vapor intrusion, continues as recently as August 2023.

Of the 11 sites, there are three RTNs that have been closed under an Activity and Use Limitation (AUL). An AUL documents that there is a presence of oil and/or hazardous material that continues to contaminate a site. An AUL is a legal document that establishes how the site may be used and the activities that can be performed on the site. The three RTNs that include AULs are the following:

- Two RTNs associated with 700 Aiken Street (3-0031287 and 3-0031602), both of which are closed under an AUL due to remaining elevated concentrations of petroleum aromatic hydrocarbons and petroleum hydrocarbons. The AUL limits the excavation of soil below 9 feet or if blue soil is observed without the consultation of a Licensed Site Professional (LSP).
- One RTN (3-0001328) for contaminated groundwater from a gas station located at 443 Bridge Street was filed and the site was closed with an AUL to prevent access to contaminated groundwater associated with fuel spills.

The remaining sites were all closed under either Class A1 or Class A2 Response Action Outcome Statement (RAO) meaning contaminants have either been reduced to background concentrations or have been remediated so there is a condition of no significant risk without the use of an AUL. Accordingly, based on this investigation of existing resources, there is a low apparent risk of encountering hazardous materials or soils during construction in the project area.

5.3.5 Boring Program

CDM Smith is also conducting a boring program to determine subsurface soil conditions for pipe bedding and support. Concurrent with these geotechnical borings, CDM Smith is conducting environmental sampling at selected bore hole locations along the proposed main conduit to identify potential hazardous materials. Specific reference to potential areas of contaminated soils will be included in the contract documents and the construction contractor will be required to be prepared to institute proper procedures to minimize the cross contamination of clean soils and to ensure that appropriate health and safety measures are taken to protect both the workers and the public. These procedures will also include reference to pertinent state and federal regulations for the handling and disposal of excess excavated material that may result from the construction.

5.4 Public Relations

A well-informed public is critical to a successful construction project. A lack of public outreach can create significant project delays, public relations concerns for the utility, and long-term negative impacts for all parties involved.

As the work on this preliminary design report has progressed, good lines of communication and public notification have been created working in unison with the Department of Planning and Development, and that framework should continue throughout the final design and construction phases of the project. Public notifications, newspaper articles, neighborhood public meetings, City Council meetings, and social media blasts will all be instrumental in keeping the public informed of the project. Public meetings held in the design stages will be important to solicit local knowledge of issues and of potential construction impacts so that final design documents can adopt approaches to mitigate these impacts (particularly related to property access, safety, traffic management, utility services, and construction activities). In addition, CDM Smith has worked with the City to develop the online Lowell Sewer and Street Flooding Issues Survey described in Section 2. This survey, that can be found on the LRWWU website linked here https://www.lowellma.gov/637/Wastewater-Utility, will allow the public to provide real time input on various issues in the project area.

This public outreach effort will continue through the construction phase using a similar public notification process. Flyers, door hangers, notices, newspaper articles, neighborhood public meetings, City Council meetings, and social media blasts can be instrumental in mitigating issues before they arise. Notices may be provided to residents announcing special construction activities such as blasting, detours, parking restrictions, relocated bus stops, etc. An experienced on-site Resident Engineer whom is visible to the public, together with a public relations component aimed at inviting public feedback, helps to formulate a proactive response to anticipate issues and create resolutions ahead of time.

5.5 Constructability Review

During preparation of the preliminary design alignments, CDM Smith completed a site walk along the proposed routes with a resident construction engineer and City staff to identify key construction issues such as the location of wetlands, surface conditions, traffic, general condition of existing roadways, sensitive receptors, and areas of concern, etc. Based on these observations, initial constructability challenges were identified along each of the major pipe routes to consider the potential impacts, mitigation measures, and general feasibility.

To facilitate a further evaluation of these construction impacts, a preliminary work zone was developed to consider the local road and residential impacts. The focus area was West Street, from Hildreth Street to Lakeview Avenue, where the initial alternative pipe route suggested the construction/installation of a 5-foot wide by 8-foot deep box culvert along this very narrow street to complete the drain system outfall to the Merrimack River. This is considered the “worst-case” scenario but does represent the level of construction impact that may occur on adjacent streets like Stanly Street, Coburn Street, and Jewett Street along with some of the small cross streets. In these areas, the single and multi-family dwellings are located very close to the narrow streets, sometimes right along the back sidewalk line, which provides very little buffer to the construction along the street.

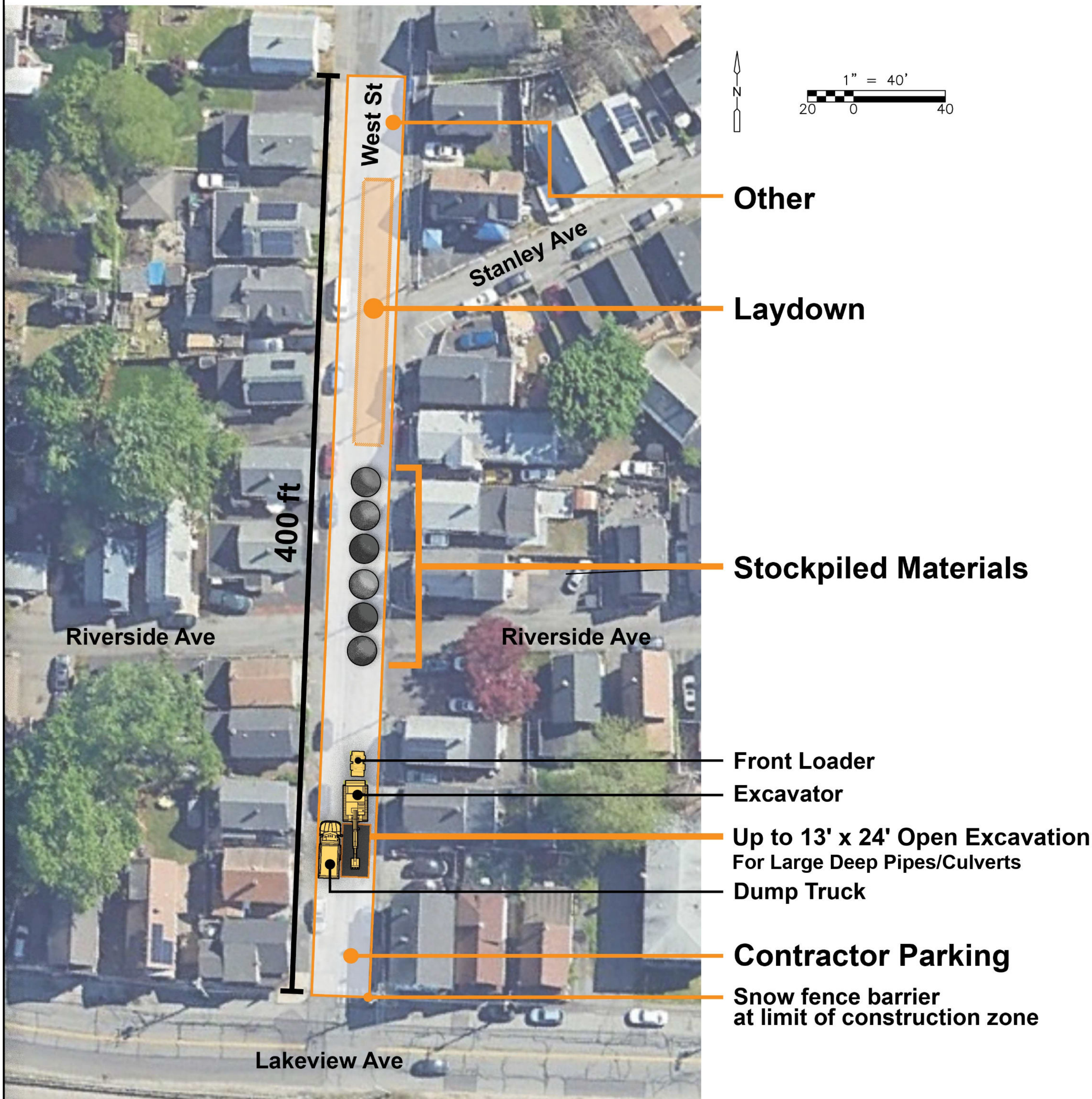
For this visualization, the work zone was estimated to be approximately 400 linear feet of roadway, as shown in **Figure 5.3**. This would accommodate areas for construction equipment, laydown area for trench support devices, and stockpiled materials. The work zone would be enclosed by a snow barrier fence. (Concrete barriers might also be used as long as they did not have to be moved every day, which could shorten the daily work period). **Figure 5.4** shows a street view of the potential impacts of construction equipment operating along a street, like West Street, with a very narrow width.

During construction, many roadways will be closed except for sidewalks, and detours will be identified. Housing access and on-street and off-street parking will be impacted and will create disruption to the neighborhood. During the day, an off-street parking area with transportation may be required to allow residents access to their homes, work, and outside activities during the day.

During working hours, access to the properties for emergency services will need to be coordinated with the police officers on detail. In the evenings, after work hours, the streets will ideally be reopened to the public and vehicles. Metal plates will be installed on top of the open excavation at the end of each day.

Disturbances to the street could be substantial for this particular construction example and full depth pavement restoration from curb to curb could likely be required based on this construction disturbance. Existing curbs may need to be removed and reset and potentially replaced. Existing gas and water utilities would likely need to be replaced to accommodate the large drain pipe and establish a right sized corridor for the excavation and installation of the box culvert with trench support. The existing combined sewer may also need to be temporarily redirected based on the space available to install the new box culvert.

The evaluation identifies the “worst case” situation in this project area, i.e., the largest pipe getting installed along one of the narrowest streets. Other streets in the project area have less challenging construction impacts and are more likely similar to the type of sewer separation work undertaken by the Utility in its past projects. This potential for construction impacts was taken into consideration in the selection of feasible and practical pipe routes in Section 6.



Lowell, Massachusetts
Centralville Sewer Separation PDR
Figure 5.3
Typical Excavation Plan

Lowell, Massachusetts
Centralville Sewer Separation PDR
Figure 5.4
Lowell Street Disturbance

5.6 References

[1.] U.S. EPA AP-42, Fifth Edition, Office of Air Quality Planning and Standards Research Triangle Park, NC, 1995. Accessible at https://www.epa.gov/sites/default/files/2020-09/documents/toc_kwrd.pdf

6.0 Development of Alternatives

6.1 Introduction

The goal of this preliminary design is to develop an approach that effectively and economically removes the surface water inflows (Humphrey's Brook, Billings Street Wetlands, and Hovey Field Wetlands) and separates the CSS in the Centralville Sewer Separation project area. Removing stormwater and surface water from Lowell's CSS will help to reduce the frequency and volume of CSOs at the West Diversion Structure (Outfall (#008)) and, to a lesser degree, at other CSO regulators connected by the interceptor system. In addition, sewer separation will help to address system surcharging and street flooding, as discussed in Section 2, and infrastructural renewal needs and I/I reduction as discussed in Section 3.

Section 6 summarizes the development of alternatives to effectively separate portions of the Centralville CSS . The analysis revisits concepts presented in the 2000 HB PDR, considers other concepts for removal of Humphrey's Brook, and advances the evaluation of alternative pipe routes and drain system outfall discharge locations based on a range of design storms that incorporate climate change.

Given the large size of the Centralville CSS and the requirements of the Final 2023 CD, separation of the CSS in the 2000 HB PDR area will be accomplished in phases. Phase 1 will focus on the removal of inflow from Humphrey's Brook and the Billings Street Wetlands, and possibly inflow from the Hovey Field Wetlands. The remaining CSS within the 2000 HB PDR area will be separated into one or more subsequent phases.

Section 7 Alternatives Analysis discusses the most feasible alternatives with the estimated project costs and the goals of the City to address the CD requirements and existing system surcharging and street flooding.

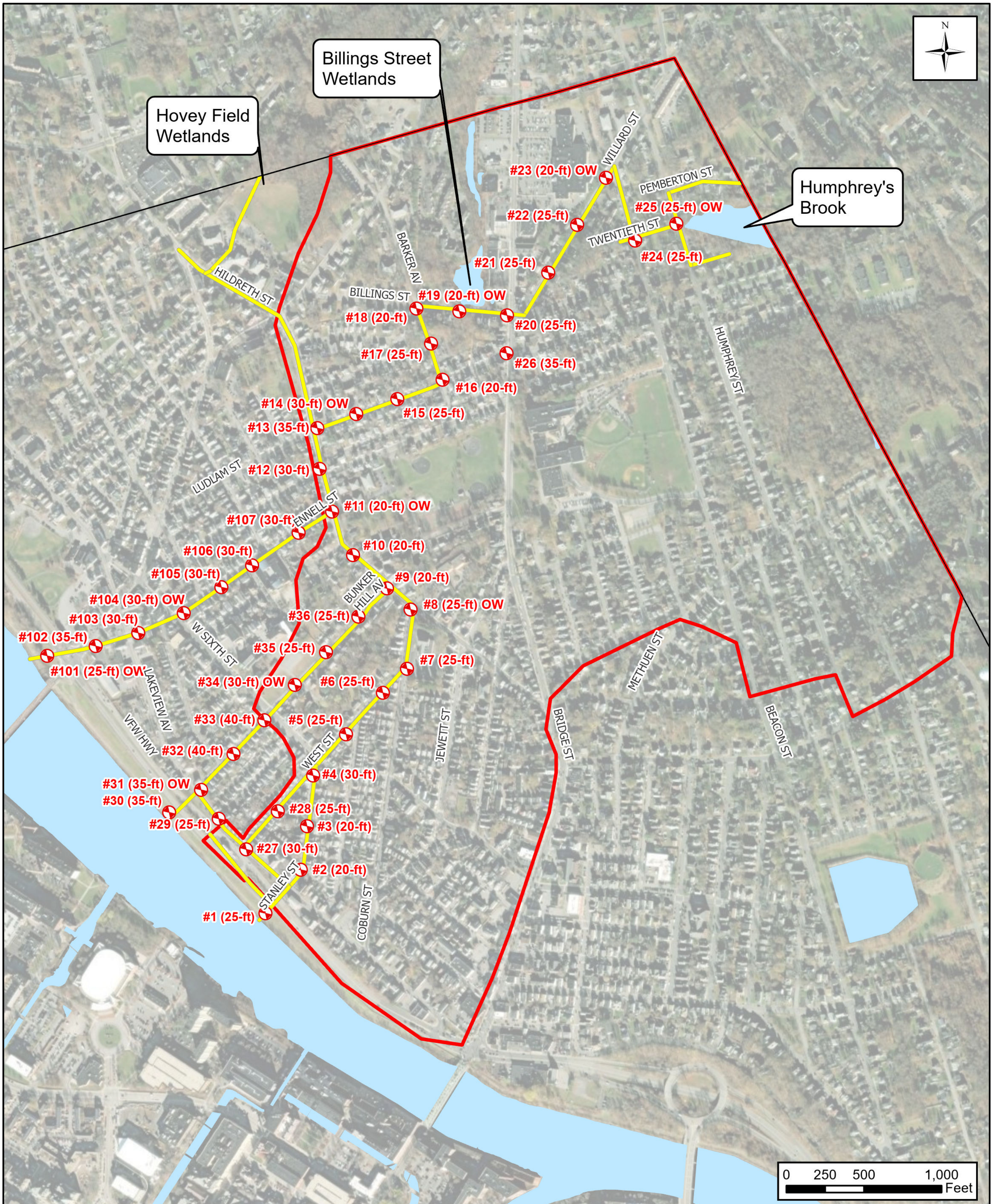
6.2 Base Mapping and Field Investigations (Survey/Borings)

Base mapping is necessary for the development of 20-scale design drawings of pipe routes to identify underground utility conflicts and establish pipeline inverts and depths to consider the feasibility and construction challenges of each alternative pipe route. This base mapping for this project was prepared using a combination of existing City GIS data and solicited utility information as discussed further below. Select utility sewer record drawings were also reviewed for potential bedrock along the alternative pipe routes (if noted on the drawings).

Volume 2 of this PDR includes a set of preliminary design plan and profile drawings. These drawings were used to develop the most practical routes for new piping and determine the appropriate depth for new pipe, with consideration to general constructability issues and the need to minimize community impacts and avoid utility conflicts to the extent possible. The pipe size/length information presented in this section is based on the hydraulic model developed for this project and may vary slightly from the pipe lengths shown on the preliminary design drawings.

Final survey and borings have been initiated along the potential main conduit routes (identified further below) to confirm actual positions of underground utilities within the street right-of-way and to identify subsurface soil conditions to determine pipe support and bedding requirements, bedrock depth, and trench support requirements. This comprehensive topographic survey will be used to develop the Phase 1 design drawings for bidding and construction.

Figure 6.1 shows the current extents of final survey and borings along pipe routes that is being completed now. This field work was initiated after the primary alternative routes were identified.



CDM Smith | DUCK ISLAND LOWELL REGIONAL WASTEWATER UTILITY

Legend

Proposed Boring

Approximate Survey Extents

2000 HB PDR Area

OW - Observation Well

Lowell, Massachusetts

Centralville Sewer Separation PDR

Figure 6.1

Final Survey and Borings

6.2.1 Base Mapping

The City's GIS database is a robust source of information that was used to create preliminary base maps. The database includes property parcels, streets, pavement limits, buildings, select hydrologic features, utility poles, and surface contour information. In addition, it also has an inventory of assets including information on sewers, drains, manholes, and catch basins, which was also supplemented with available sewer and facility record drawings. The City's GIS also provided information on water main alignments and sizes. For private utility information, CDM Smith contacted Verizon and National Grid for information regarding the size and location of communications, gas, and electric utilities in the project area. For final design, this base mapping information will be supplemented with information provided by an ongoing field survey.

6.2.2 Geotechnical Investigations

As part of final design, in-situ subsurface investigations were initiated to obtain data to inform the final design. These investigations include borings to characterize the soil conditions below the potential pipe invert, geotechnical samples for laboratory analysis, groundwater depths, and environmental/potential pollutant conditions. As noted above, subsurface conditions will be a factor in the project costs to excavate, dewater, install, and support the pipe and connecting manholes.

Figure 6.1 shows forty-three (43) borings that are currently planned in the project area. The borings are located approximately every 300-feet along potential pipe routes and range from 20 to 40-feet in depth (extending to approximately 10-feet below the proposed pipe invert). Each boring is being pre-cleared using a vacuum excavation method to minimize the disturbance of existing underground utilities.

Geotechnical samples for soil laboratory analyses will be taken continuously between a boring depth of 0 to 10-feet, and then at 5-foot intervals, to further characterize the soil stability and content. Bedrock depths will be noted at refusal but rock cores will also be taken to an addition depth of 10 to 15 feet below refusal to confirm bedrock or boulders.

At ten of the boreholes, an observation well (OW) will be installed to monitor the groundwater table. Groundwater information will be used to identify the dewatering measures needed during construction. The OWs in this project were spatially located to characterize groundwater depths in the project area to anticipate potential trench dewatering issues. Groundwater levels will be checked periodically during project design and construction.

The geotechnical investigations began in November 2023 and will continue through February 2024. The information obtained during this program will be summarized in a memorandum and will be used to advance the final design of the main conduit. Focused geotechnical analysis reports may be required if unsuitable pipe bedding conditions are discovered and a mitigation solution must be identified.

6.2.3 Environmental Data Evaluation

Environmental soil samples will be collected at each boring for excess soil disposal pre-characterization. As discussed in Section 5, the MassDEP Waste Site & Reportable Releases database was consulted to identify any potential waste sites in the project area. One site with an open and active Regional Tracking Number (RTN) was discovered in the project area at the intersection of Willard Street and Humphrey Street; as a result, extra soil sampling was targeted in this area. Two sites at 700 Aiken Street have closed RTNs but have Activity and Use Limitations (AULs) filed for the properties. These sites likely have contamination remaining below the ground surface on the site and there is a chance that contamination could be encountered in the right-of-way adjacent to these sites. In that event, a Licensed Site Professional (LSP) may have to be engaged by the construction contractor during excavation.

Soil samples are being collected at every boring within the first five feet of depth with the vacuum excavation pre-clearance. A photoionization detector (PID) will be used to continuously monitor the boring headspace for VOCs during the advancement of the borings. If the PID is triggered, additional environmental samples will be taken to characterize this potential contamination zone. In addition, a second sample may be collected at select locations where deeper pipe installation is anticipated.

All soil samples will be analyzed for the parameters required to determine whether it is classified as clean or contaminated for the ultimate disposal options for the potential excess excavation materials.

To date, 26 soil samples were collected from 23 borings and analyzed at the environmental laboratory. So far, all results meet Massachusetts Contingency Plan (MCP) RCS-1 reportable concentrations. Minor detections of PAH's, tetrachloroethene, and background levels of metals have been observed, but all results have met RCS-1 standards and are not classified as contaminated. All testing and results will be compiled during the project final design phase.

6.3 Reuse of the Existing Combined Sewer System

Reuse of an existing CSS as a drain system (and construction of a new sewer) is typically considered as an option to the installation of a new drain system as a CSS separation approach. This option works best if there are no known system surcharges or street flooding that would suggest that the existing system had deficient capacity. A similar analysis was completed in the 2000 HB PDR and the report suggested that a new drain system be constructed with the existing CSS rehabilitated for continued use as a sewer.

The advantages and disadvantages of these two approaches were revisited for this study; although, it is important to note that the downstream areas in Centralville have reported street flooding during severe rain events that suggest a new larger drain system is warranted. **Table 6.1** summarizes the advantages and disadvantages of using the existing CSS as a wastewater collection or stormwater collection system, which are discussed further below.

Table 6.1 Re-Use Analysis Summary

Combined Sewer as a Stormwater Collection System (Build New Sewer System)		Combined Sewer as a Wastewater Collection System (Build New Stormwater System)	
Advantages	**Disadvantages**	**Advantages**	**Disadvantages**
Infiltration Reduction	Creates Elevation Conflicts	Flexibility in Construction	Minimum Pipe Velocities
Maximum Use of Surcharge Conditions	Deep Construction	Reduced Flow Handling	Integrity of Existing System
---	Increased Flow Handling	Less Complicated Construction	Creates Conflicts with Utility Services
---	Requires TV Inspection of Existing System	Option of Slip-Lining Existing System	Requires Smoke Testing of Existing System

6.3.1 Use of Combined Sewer as Stormwater Collection System (Build a New Sewer System)

This approach considers the use of the existing combined system as a stormwater collection system and construction of new sanitary sewers to serve the project area.

6.3.1.1 Advantages

Infiltration Reduction

The Utility conducted a metering program during the Spring of 2023 and an I/I Analysis Report to evaluate the amount of I/I in the existing CSS will be completed by January 31, 2024. New manholes and sewer pipes could significantly reduce the amount of infiltration entering the sewer system.

Maximum Use of Surcharge Conditions

Many upstream areas of the CSS are adequately sized to convey peak stormwater flow generated by a 5-year storm event. If surcharge to road depth is considered, the existing pipelines could convey flow generated by larger storm events. If new, more shallow, drain lines are considered, the surcharge potential is less as will be the ability to minimize pipe sizes.

6.3.1.2 Disadvantages

Sewer Service Conflicts

Property sewer service connections are connected to the existing combined sewer in each street typically with a sloped service directly the sewer. Converting the CSS to a storm drain creates an elevation conflict for every sewer service connection within the project area. This situation requires that either the new sewer be lower than the invert of the “former CSS” drain to connect at least one side of the street and/or have two parallel deep sewers. New sewer services on at least one side of the street would be run under the existing system, which may result in pipe failure with adjacent construction if the existing piping is not first rehabilitated. A deeper sewer also increases the need for more rock excavation in some areas of the project.

Making the new sewer pipe deeper is also a challenge as the new sewer must connect to the North Bank Interceptor system at the end of the run. Accordingly, the deeper invert must be raised at some point to match the existing inverts at the end.

Finally, the existing 96-inch North Bank interceptor is also a direct elevation conflict for the reuse of the existing combined sewer because its invert is currently at the same elevation. Accordingly, to use the combined sewer near its discharge point, a new large diameter pipe would have to be installed to either raise or lower the new “drain” to cross above or below the existing sewer interceptor to discharge into the river.

Depth of New Sewer System – Excavation and Installation Considerations

A new wastewater collection system must be constructed at a depth below the existing system to ensure that all connections currently entering the CSS can be accommodated by the new sewer. Available sewer records indicate that bedrock is present in the project area and this is confirmed by rock outcroppings observed during field visits and preliminary results from the ongoing geotechnical program that is estimating bedrock depths and soil conditions.

Flow Handling

The handling of existing flow while constructing a new wastewater collection system, including the probable replacement of portions of the combined sewer mainline, would significantly increase the complexity and cost of the project.

TV Inspection of Existing System

If the CSS were used as a storm drain system, confirmation that all wastewater connections had been removed from the system would be required, adding complexity to the project. Use of the historical CCTV inspections recently conducted and described in Section 3 could help verify connections; however, additional dye testing may be required in some cases.

Section 3 summarizes manhole and pipeline assessments completed as part of the current project. These assessments found that the existing CSS is generally structurally sound but may require extensive rehabilitation as most of the pipe in the project area is approaching the end of its useful life.

6.3.2 Use of Combined Sewer as Wastewater Collection System (Build a Stormwater System)

This alternative considers using the existing combined system as a wastewater collection system and constructing new stormwater systems to serve the project area.

6.3.2.1 Advantages

Flexibility in Construction

There is more flexibility in constructing a new stormwater collection system than there is in constructing a new wastewater collection system, as drains only need to extend far enough to capture existing catch basins and surface collection patterns can be modified. For example, due to drastic changes in elevation in the 2000 HB PDR area, some streets with steep slopes could use time of concentration along a street curbline and effectively capture stormwater runoff at the end of the street, thus eliminating a new pipe.

Several streets would only require a new drain to extend up a portion of the street to effectively collect the stormwater from the entire street. In contrast, the limits of a new wastewater collection system are more strictly defined by the properties that need to be served and, as a result, often require longer lengths of pipe. The shorter length and shallower depth of a new stormwater system results in a cost savings when compared to the cost of constructing a new wastewater collection system.

Flow Handling

Another advantage of keeping the existing system as a wastewater collection system is that the permanent wastewater collection system would be intact and operational during construction. This makes construction of the project much easier, as the existing system would continue to operate as it normally does while the new stormwater collection system is constructed. This eliminates many of the flow handling concerns associated with construction of a new wastewater collection system.

Overall Constructability

Although a new stormwater collection system would require larger pipes than a wastewater collection system, installation of a stormwater collection system would be easier due to the relatively shallow depth of the drains and the substantially fewer number of connections that would need to be made to a stormwater collection system. The new stormwater system would only require the connection of catch basins and other inflow sources.

Options of Rehabilitation of Existing System

Another advantage of using the CSS as a wastewater collection system is that there would be a substantial amount of excess capacity in the collection system after removing the stormwater component; this excess capacity provides flexibility in applying rehabilitation methods which may reduce the inside pipe diameter. CIPP lining is recommended for most pipeline rehabilitation; however, in certain applications, slip lining could be utilized where there are severe structural concerns. .

6.3.2.2 Disadvantages

Maintaining Minimum Velocities

Removal of stormwater flow from the CSS would reduce flow velocities within the system and create the potential for accumulation of sediment and debris, which commonly causes maintenance and odor problems. Velocity calculations were performed on many of the larger pipes in the CSS to determine if minimum velocity requirements (usually 2 feet per second) are maintained if the stormwater flow is removed from the system. The 2000 HB PDR analyzed portions of the existing system and concluded that most pipe velocities would be between 1.5 to 3 fps without stormwater flow, indicating that the existing CSS should function properly with only wastewater.

Integrity of Existing System

The overall condition of the existing system is an important factor in recommending its reuse. If the CSS were found to be in generally poor condition, there would be benefit to constructing a new sewer system and using the existing system as the stormwater system.

Section 3 summarized the existing system conditions assessments completed as part of this project. Overall, the existing CSS was found to be in good condition. Recommendations for rehabilitation and replacement of portions of the existing system can be implemented as part of the sewer separation program.

Conflicts with Utility Services

The construction of new storm drain systems, usually starting with 4-feet of minimum cover, commonly results in numerous conflicts with existing water, gas, and sewer service connections, which often range from 3 to 6 feet of cover. Services impacted by construction are typically replaced all the way from the utility to the property line, which disturbs curbing and sidewalks. Potential impacts to services, and related disruption to curbing and sidewalks, must be accounted for during preliminary design and in the cost estimate for the proposed work.

6.3.2.3 Conclusion

Because of concerns regarding the constructability and cost of constructing a new wastewater collection system, the preliminary design of the Centralville Sewer Separation project will be based on using the existing CSS as the wastewater collection system and the construction of a new stormwater collection system. However, there may be limited exceptions for certain streets as the design of each separation area advances.

6.3.3 Sump Pump and Roof Drain Connections

The elimination of in-home sump pump and roof drain connections will be evaluated under any separation project. Sump pumps and roof drains commonly discharge directly to the local CSS through existing service connections. Educating homeowners on the importance of removing these connections from the local sewer is a crucial element affecting the success of any disconnection program. Further investigations are required to determine the magnitude of sump pump and roof drain connections in the Centralville CSS area. The City is implementing an online Sewer and Street Flooding Issues Survey which includes questions about whether buildings have sump pumps and where these pumps discharge. This information will be helpful in identifying properties that have sump pumps; however, follow-up inspections will be necessary to confirm survey results.

The City has already successfully implemented sump pump and roof drain disconnection programs as part of the sewer separation completed under multiple construction contracts from the years 2002 to 2012. During that time, more than 2,200 property investigations were completed in those areas. As new drains were installed, the Utility disconnected existing drain connections to the sewer system and provided sump pumps to property owners who may have been draining groundwater around their basement through their sewer cleanouts. The Utility tried several approaches to inflow removal including “Splash” solutions outside the home and connecting to drains to avoid future sewer reconnections. The Utility plans to apply these practices on future separation projects based on past success.

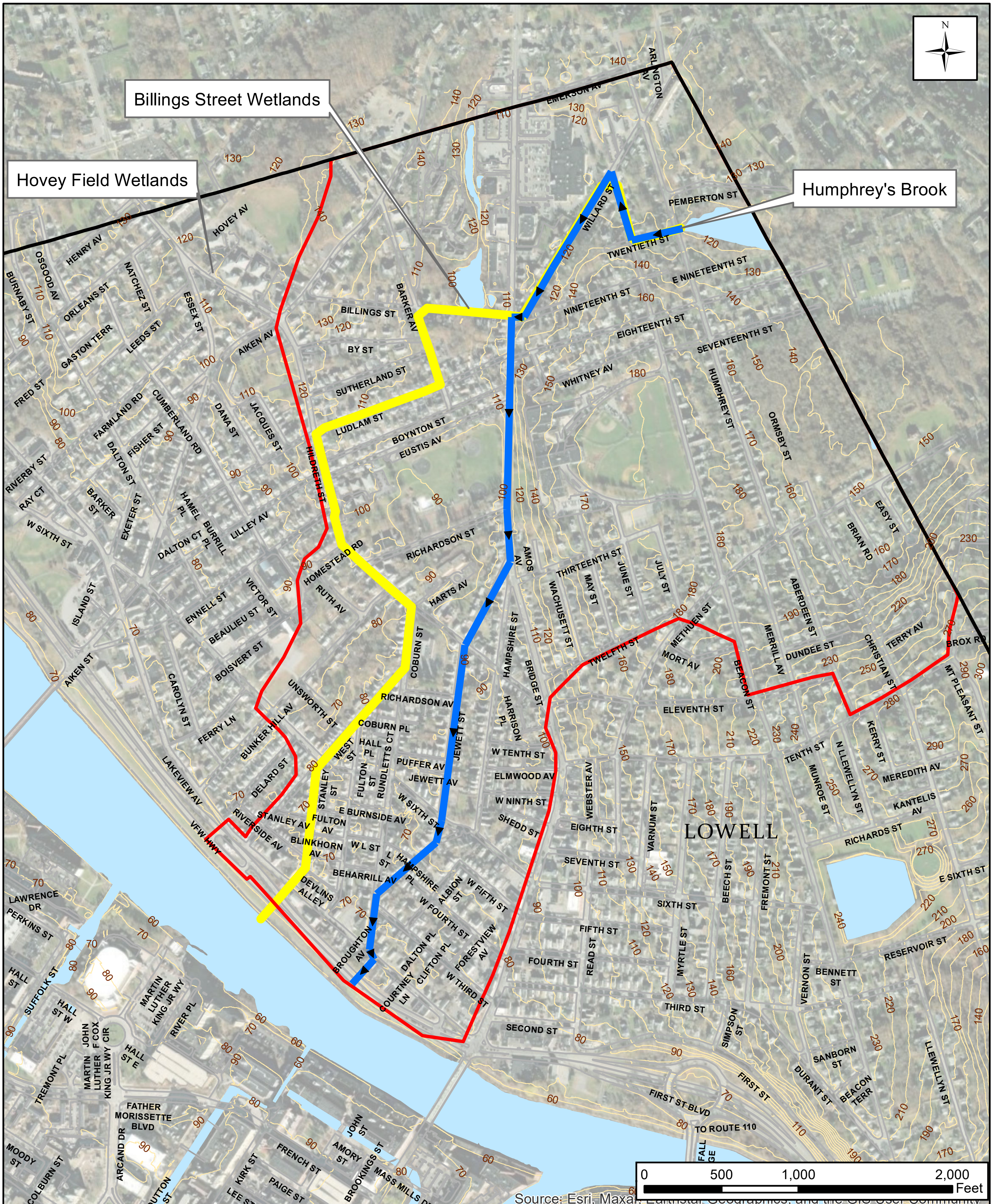
6.4 Humphrey’s Brook Direct Removal Concepts

Given that Humphrey’s Brook and its tributary areas cause the inlet sizing to start at a minimum of 36-inches, the feasibility of diverting the brook towards the Merrimack River using trenchless conduits was considered, as this would substantially reduce the size of the remaining separation study area. **Figure 6.2** shows that the most direct route on City owned land is down Bridge Street, which would have a depth range of approximately 20 to 30 feet. This concept was discussed with the Utility in early workshops and it was determined that this option was not viable due to the construction, cost, schedule, and permitting challenges described below.

The idea of using a micro tunnel boring machine (MTBM) was considered given the initial size of the original inlet of the 2000 HB PDR (36 to 48”). Typically, an access pit needs to be dug at each change in direction, which can be costly as the pits are large and can be a major interruption to traffic, particularly along a heavily trafficked areas such as Bridge Street. The Bridge Street route was considered favorable for use of an MTBM because the route is relatively straight, thus reducing the need for pits.

One of the problems with using Bridge Street as a pathway for a main conduit is that Bridge Street is in the middle of the basin, making it difficult for separation branches on the western side of the basin to connect, as they would slope against grade and therefore be deeper. Deep branches require more excavation support or costly trenchless installation methods. Connection of the separation branches would require drop shafts which are costly due to the complexity of the connection to the mainline. There are also hydraulic and air venting challenges associated with dropping large amounts of flow in a vertical drop.

Because of these many alignment, technical, and implementation challenges associated with this concept, the concept of micro tunnel boring as part of this project was quickly determined to not be practical and eliminated form further consideration.



Legend

- 2000 HB PDR Area
- Concept Trenchless Alignment
- Original 2000 Humphrey's Brook PDR Route
- Topography Contour

Lowell, Massachusetts

Centralville Sewer Separation PDR

Figure 6.2

Concept Trenchless Alignment

6.5 Methuen Street Separation Area Alternatives

The Methuen Street Area is unique due to its location and topography, which is why the 2000 HB PDR suggested having its own compartmentalized sewer separation solution. Situated directly on the Lowell-Dracut border and at the northern base of Christian Hill, few practical options exist for constructing a new gravity pipe for separation. As described in Section 2, the CSS flows by gravity to the local low point at the base of Easy Street, over the Lowell-Dracut border, and cross-country to the Humphrey's Street sewer. The cross-country CSS picks up flow from Seventeenth Street and Eighteenth Street.

Two alternatives were analyzed for serving the Methuen Street Area: 1) construction of a drain outfall utilizing the existing culvert at the Methuen Street/Easy Street Intersection; 2) construction of a new sewer for the Methuen Street Area;

Consideration was briefly evaluated if a stormwater system could be directed west against grade to connect to other proposed drainage near Twelfth Street. This alternative would require installation of a pipe up to 40 feet deep, making this option unappealing for both construction and maintenance. Alternatively, the use of a stormwater pump station to provide for a smaller, shallower force main in the same location is not favorable given the infrequent and wide range of flows. For these reasons, this alternative was eliminated from further consideration.

6.5.1 Alternative 1 – Drain Outfall Utilizing Existing Culvert at Methuen Street/Easy Street Intersection

This alternative would involve constructing a new drainage system in the Methuen Street Area and utilizing the natural topography to flow stormwater east to the Easy Street / Methuen Street intersection and discharge to an existing 30-inch diameter outfall. The outfall culvert accepts the small existing drainage pipe on Easy Street and discharges to an unnamed wetland area in Lowell that is tributary to Humphrey's Brook.

As part of the 2000 HB PDR, field investigations were performed to evaluate this option. Two areas that received attention were the existing headwall off Methuen Street and a culvert crossing on Eighteenth Street, approximately 1500 feet downstream of the proposed discharge point. The existing headwall off Methuen Street would likely need to replaced to accommodate a larger outfall pipe. A new headwall with wing-walls and riprap was proposed to help stabilize the banks adjacent to the outlet.

The flow discharged from this area would travel more than 0.5 miles through open channels before reentering the proposed stormwater collection system at the Humphrey's Brook inlet. The only hydraulic restriction between Methuen Street and Humphrey Street is a culvert crossing under Eighteenth Street. To minimize any impact from adding additional flow to Humphrey's Brook between Methuen Street and Humphrey Street, it was recommended that the culvert under Eighteenth Street be replaced with a new, higher capacity culvert.

As part of the 2000 HB PDR, performance of the existing brook system between Methuen Street and Humphrey Street was assessed using the 10+ year storm that occurred on September 10, 1999. This investigation determined that the brook has capacity available to handle excess stormwater flow from the Methuen Street area. Confirmation of the culvert upsizing will be done in final design along with the design of modification/replacement of existing headwalls and culverts. A new easement would also need to be obtained.

6.5.2 Alternative 2 – Construct a New Sewer for the Methuen Street Area

This alternative would involve constructing a new sewer for the project area, which would allow the CSS to carry stormwater only. New gravity sewer lines would extend to every property currently linked or tributary to the cross-country sewer line on Methuen Street (194 addresses). This alternative was discussed in the 2000 HB PDR and revisited in the current study as described below.

Sewer flows from 158 of the Methuen Street Area residences would be collected by gravity to a proposed Ormsby Street wastewater pump station. The pump station would pump flow through either a 4- or 6-inch diameter force main along Ormsby Street and Methuen Street and connect to the existing combined system near the Methuen Street/Merrill Avenue intersection. The City has identified undeveloped, open land at the end of Ormsby Street that could serve as a potential spot for a new pump station.

A second wastewater pump station would be needed to serve the remaining 36 residences located on Seventeenth Street and Eighteenth Street, which currently flow into the 30-in cross country sewer in Dracut prior to Humphrey Street. The pump station would be located either along Seventeenth or Eighteenth Street and would pump flow through a 4- or 6-inch diameter force main. The force main would connect to the existing combined system on Humphrey Street. Conceptual sizing and estimated peak flows for the two new pump stations are shown in **Table 6.2**.

Table 6.2 Conceptual Methuen Street Area Pump Stations Sizing

Area	Ormsby Street Pump Station	17^{th} / 18^{th} Street Pump Station
Residences	158	36
Calculated Peak Flow (GPM)	170	38

Advantages

The existing 30-inch diameter cross country combined sewer passes through wetland areas between Lowell and Dracut on its way to Humphrey Street. It is likely that I/I in this area is significant; however, this needs to be investigated further. Using the existing CSS for stormwater conveyance eliminates this I/I component from the existing wastewater collection system and reduces flow to Duck Island.

Disadvantages

This alternative has several disadvantages, including:

- When compared with constructing a new drain for this area, more streets will be impacted by construction activities. The current Methuen Street sewer area would need to be completely replaced, except for Easy Street and Christian Street, which extends further than the required drainage.
- The low point at the Easy St and Methuen St intersection would require that the new sewer on Methuen Street be extremely deep. On the east side of Methuen Street to Ormsby Street, the

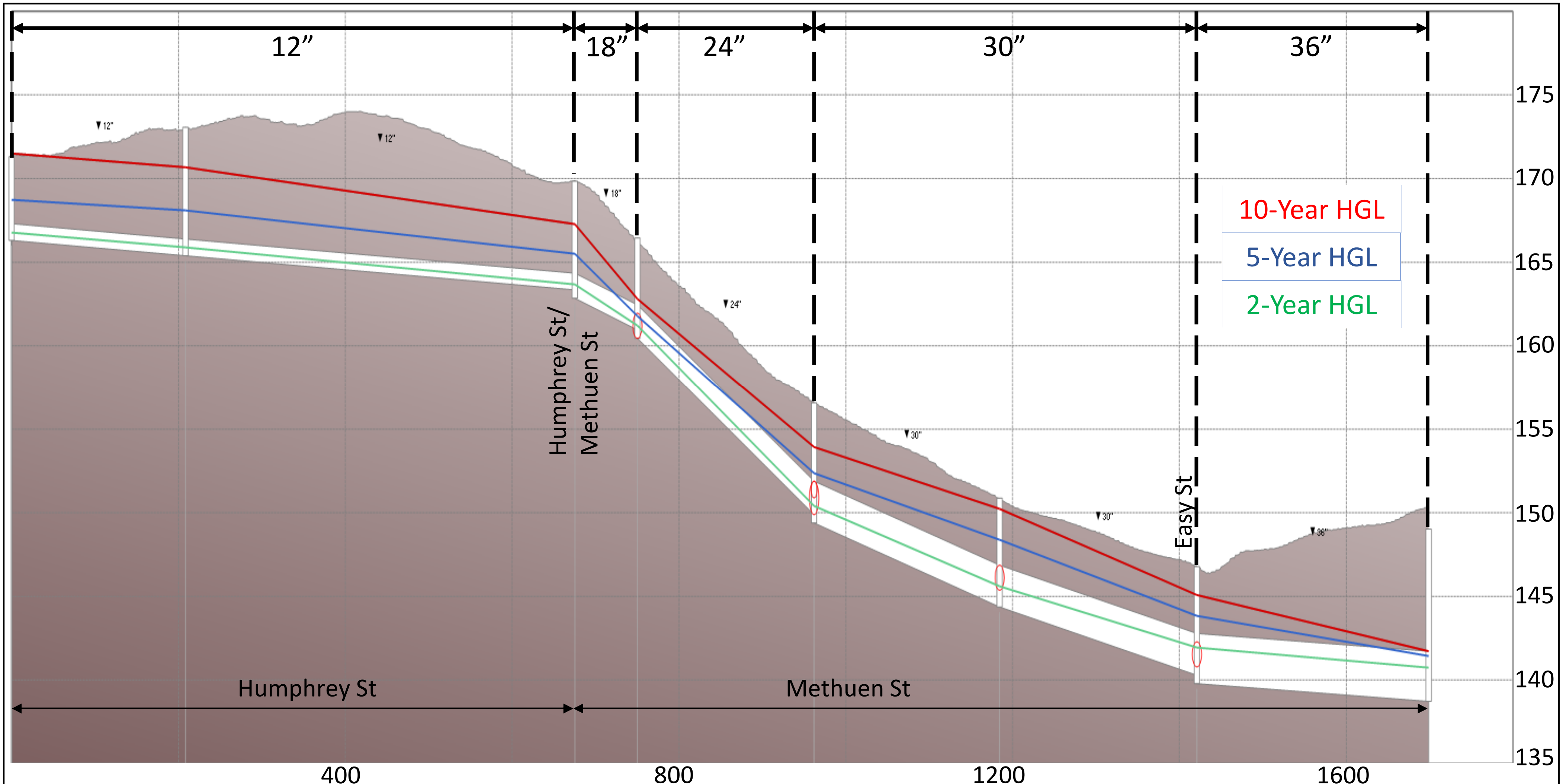
new sewer would be nearly 27 feet deep at the deepest point. This pipe depth would result in increased construction, maintenance, and coordination costs.

- The additional cost of constructing, maintaining, and operating two new wastewater pumping stations and force mains, and new gravity sewer lines with house laterals. These costs are directly proportional to flow rates and the required pumping head for the station.

For these reasons, this alternative should not be pursued further unless other alternatives prove infeasible.

6.5.3 Methuen Street Sewer Area Conclusion

The most economical and practical solution to separating the Methuen Street area is by construction of a new drainage line that discharges to the existing Easy Street culvert (Alternative 1). **This separation plan is a recommended component of all subsequent alternatives so will not be included in subsequent evaluations presented in this PDR**. **Figure 6.3** shows the peak hydraulic grade line profile along Methuen Street for various design storm events. It should be noted that there are a few existing drains on side streets which may be undersized for the 10-year event as shown in Section 4; however, flood concerns here is minimal as many of the streets have steep slopes towards the trunk drain on Methuen Street, meaning flow will slip to next available catch basin inlet with capacity. Methuen Street also does not have curbs, so green space can also help infiltrate some of the stormwater volume. Given the infrequency and limited duration of these storm events, it is not considered cost effective to replace the few drains on side streets which may be undersized for the 10-year storm.



Lowell, Massachusetts
Centralville Sewer Separation PDR
Figure 6.3
Peak Hydraulic Grade Line Profile for Methuen Street

6.6 Alternatives for Main Conduit for Brook Removal and Other Phased Separation

6.6.1 Common Components and Challenges

The 2000 HB PDR recommended construction of a main trunk line beginning at the Humphrey's Brook inlet, and heading west generally with the natural topography to capture Humphrey's Brook and Billing Street Wetlands. The current study also collects a third inflow source of Hovey Field Wetlands via a separation branch from northern area before heading south along Hildreth Street. This is a common component in all alternatives to be discussed below.

In general, the route follows the existing combined trunk sewer in all areas except for a short cross-country segment, where it is located under houses and a recreational park between Ludlam Street and Hildreth Street. From the inlet, the mainline would travel along existing right-of-way to Beacon Street, then northwesterly to Willard Street, and then southwesterly along Willard Steet to the intersection with Billings Street. Flow from the Billings Street Wetlands enters the mainline along Billings Street. From Billings Street, the mainline would travel along Barker Avenue to Ludlam Street and then along Ludlam Street to Hildreth Street, where it would connect a future branch drain that collects Hovey Field Wetlands. The main conduit depth would vary from 7-feet to a maximum depth of more than 24-feet at the Ludlam Street/Hildreth intersection. Then the main conduit would continue southerly along Hildreth Street towards the southern half of the study area.

After picking up the major inflow sources, the alternative routes vary as summarized separately in this section. Each of the inflow source areas will require modified or new inlet headwall structures, which will require permitting to work within wetlands and maintenance of existing brook flows into the CSS as the inlet is being constructed. Given the distance and elevation difference between the wetlands and abutters to the wetlands, bypass pumping can be minimized or even eliminated, if a slightly increased water surface elevation and wetted area within the wetland does not cause any damage.

The northern half of the main conduit route has a common size. In the 5-year design storm, the pipe ranges from 36-inches and 48-inches between Humphrey's Brook inlet and Billings Street Wetlands, where it increases to a 5-foot high by 6-foot wide box culvert (5'x6'). Although the Humphrey's Brook tributary area is larger, its influence on pipe sizes is less because it has longer time of concentration, longer brook channels, and associated wetlands to attenuate or dampen the flow currently captured compared to the other inflow areas. Due to the terrain, there are a few areas with deeper installations (as much as 25-feet) when leaving this low laying area towards the south and Merrimack River. Any deep excavation will use the slope of the terrain to quickly reduce the cover downstream to meet utility obstacles.

In the southern half of the study areas, there are additional common challenges, including:

- The need for construction of a large box culvert (minimum size of 5-feet by 6-feet) while maintaining minimal cover.

- The potential for conflicts with multiple large diameter (24-inch and larger) watermains located within West Sixth Street. Two of these watermains are abandoned but still hold water. Any adjacent work should be done with caution.
- Crossing through the levee system and the VFW highway, which was built by MassDOT on top of the levee system.
- Crossing the 96-inch interceptor system.
- High river elevations under many conditions and the potential need for backflow protection.
- Hydraulic capacity limitations which may create street flooding during events higher than 5-Year design storm. As first identified in Section 4, there is particular risk in the low laying area near Lakeview Ave, Coburn Street, and Jewett Street.

Several mainline conduit routes and branch separation network configurations were explored. The individual alternatives discuss these challenges in greater detail below.

6.6.2 Main Conduit with Outfall Near Stanley Street

6.6.2.1 Overview

Under this alternative, continuation of the main conduit becomes more complex when it changes direction south along West Street and increases to a 5-foot by 8-foot box culvert as described and shown in Section 4 (Figure 4.4). This increase in size is required because the conduit would collect storm flow from the area east of Hildreth Street and add more branches along West Street, Coburn Street, Stanley Street and Lakeview Ave. The large box culvert size exacerbates the challenges of utility congestion within the narrow corridors along West Street and Stanley Street.

The most severe utility challenge is the need for the proposed box culvert to be in the same corridor as the existing 60-inch combined trunk sewer. The box culvert height is limited to 5-feet in order to stay above the existing sewer services while providing some cover, so the width must increase to meet the required conveyance capacity. This was the initial reason for seeking other routes and reconfiguring separation connections to the main conduit.

6.6.2.2 Constructability Challenges

As alluded to earlier, the 2000 HB PDR simplified the challenges associated with the downstream crossing from Lakeview Avenue to the Merrimack River.

The first obstacles encountered in this crossing are the two existing combined sewers: a 12-inch ACP located approximately 10-feet deep along Lakeview Ave, and a 48-inch concrete pipe located approximately 12 to 16 feet deep along VFW Highway. The ground elevation is slightly higher on the VFW Highway; this means that there is minimal cover (4-feet or less) when first crossing, allowing for at least 1-foot of clearance and a 7-foot outside dimension for a 5-foot inside diameter pipe.

The VFW Highway (State Route 110) runs along the north bank of the Merrimack River, which was built by MassDOT on the earthen levee system. This is a highly traveled road consisting of two lanes in each direction, separated by a green space occupied by West Station.

The southern slope of the levee system is much steeper towards the river, which means that the last segment of pipe could daylight above the existing riverwalk. Consequently, the last segment or outfall structure is further restricted by the 96-inch North Bank Interceptor. Any portion of the flood plain occupied by the pipeline or outfall structure would require approval by flood control regulators who usually require compensatory storage to offset flood volume lost due to construction in the flood zone. Other options considered include going under the North Bank Interceptor or constructing a conflict structure, but both options have considerable challenges. Going under the interceptor is further explained in the Bunker Hill Ave alternative. A conflict structure is a structure that surrounds a portion of the interceptor at the point that the culvert is crossing, thereby allowing water to flow above and below the interceptor. The advantage of this option is that the connection could be lower, allowing the crown of the culvert to be further below the critical elevation. The concept of a conflict structure was considered but decided to be impractical because having a major interceptor in the flow of water would result in too much head loss and potentially surcharge the system.

River flood stage elevations have a critical impact on the operation of a stormwater system. If the outfall is not high enough to remain free flowing, the outfall could become submerged, thereby creating a hydraulic restriction, and causing surcharge impacts or even flooding low laying areas. The typical river elevation is approximately 54-feet and the 100-year flood elevation is approximately 69-feet. Preliminary layout of the outfall indicates that an invert elevation of approximately 58.75-feet is needed to cross above the north bank interceptor, which means that the outfall should incorporate backflow prevention with either a flap gate or Tideflex Duckbill . This elevation also puts areas closest to the river at risk of flooding if the rim elevations of structures are not above an elevation of 70-feet.

6.6.2.3 Conclusions

Combining the inflow source removal and the future separation into one mainline conduit requires a large corridor for a box culvert, which will require extensive utility relocations and protection. The new drain system profile must not conflict with typical sewer collection pipes to maintain services; however, in some instances, the creation of two local sewers to serve each side of the street may be required due to the profile conflicts. A primary concern is that, due to topography, the new drain route would share much of the same route as the existing brick (and concrete) large diameter combined sewer trunk that serves the CSS; this sewer trunk would likely require rehabilitation to protect against damage during construction. Surface impacts under this alternative are also significant given that some roads are narrow with residential homes right on the backside of sidewalks and a lack of driveways, meaning that most residents park on the street. Due to these challenges, it was decided to explore options to reduce required pipe sizes by using multiple routes to accomplish separation.

6.6.3 Main Conduit Connecting to West CSO Diversion Station

6.6.3.1 Overview

This alternative reconfigures the network so that the southern half of the Centralville area is divided into three drainage networks that culminate at Lakeview Avenue. This alternative also uses the existing West CSO Diversion Station outfall. **Figure 6.4** shows the proposed mainline conduit for brook removal (phase 1) along Bunker Hill Avenue, two other larger trunk drains along West Street and Lakeview Avenue, and the separation branches from associated separation areas (phase 2). Additional names and letter designation (example Methuen (2A)) have been added to further differentiate between the Phase 2 areas of work but these designations do not necessarily reflect individual construction contracts or a required sequence of work.

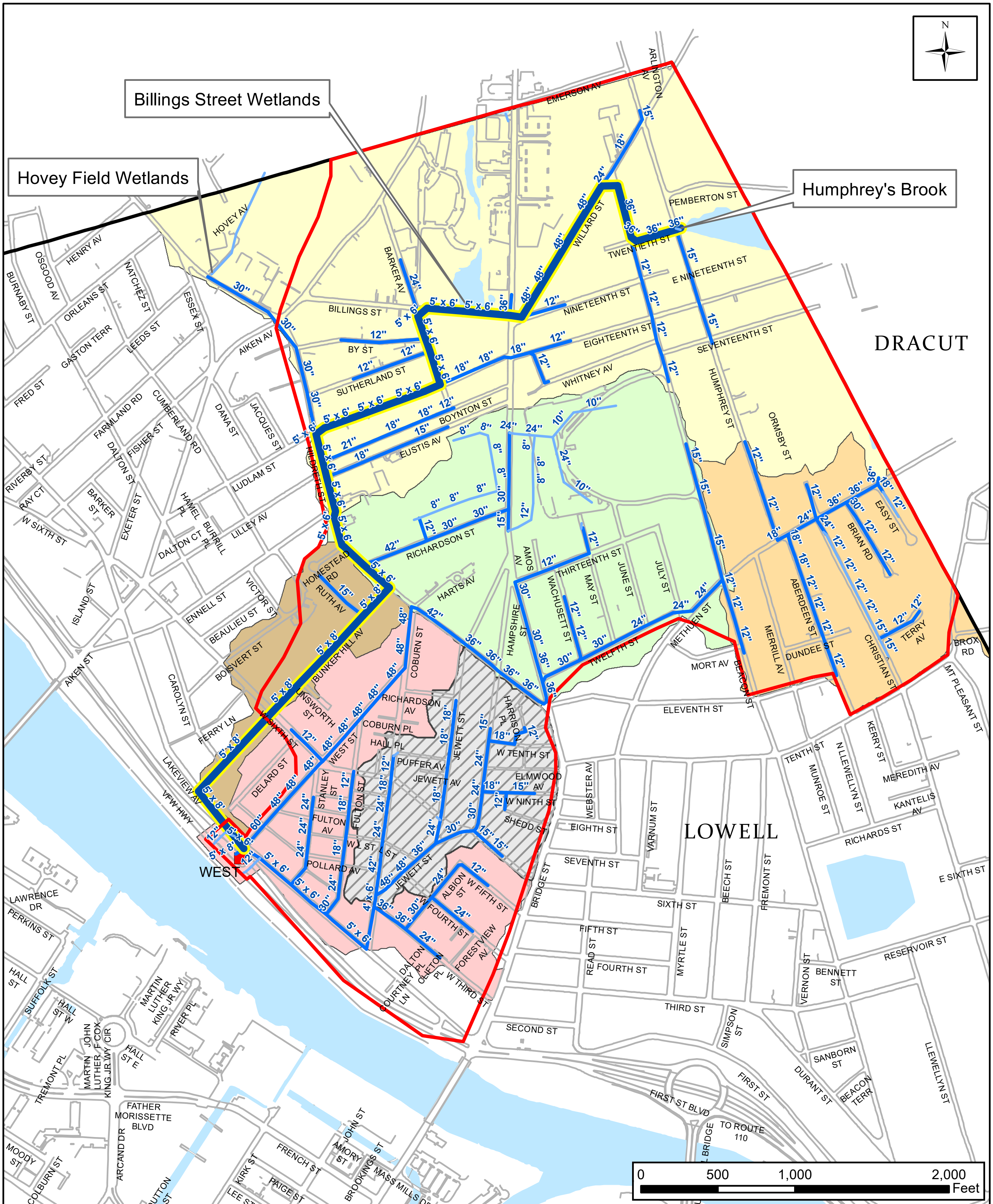
The main conduit route removing the inflow sources would follow the 2000 HB PDR route, collecting flow from the Humphrey's Brook and Billings Street Wetlands and, traveling upstream to downstream, from the Humphrey's Brook inlet along Willard Street, Billings Street, Barker Avenue, Ludlam Street, Hildreth Street; however, the current route would use Bunker Hill Avenue and culminate with other trunks drains before discharging at the West CSO Diversion Station's Outfall. This network would also include future separation of the northern branches, upper half of middle branches at Richardson Street, and Bunker Hill Avenue area.

The second trunk drain, traveling downstream to upstream, would be along West Street, Hildreth Street (East), and Twelfth Street. This network would also include future separation of the remaining middle branches, and areas along West Street.

The third trunk drain, traveling downstream to upstream, would be along Lakeview Avenue, Coburn Street, and Jewett Street. This trunk drain would allow for future separation of the remaining lower areas shown in Pink and Cross gray hatched shown in Figure 6.4. The reasoning for the subdivision of the lower area is explained further with the hydraulic modeling simulations.

6.6.3.2 Hydraulic Modeling Simulations

Hydraulic modeling of the drainage configuration described above was used to size pipes to handle a minimum 5-year design storm; the model was then used to simulate 2-year, 5-year, and 10-year design storms to assess performance, particularly the 10-year design storm to minimize any temporary flooding. The profile of the three key conduits for inflow removal and separation are shown in **Figure 6.5 through Figure 6.7**. The simulations assumed a free discharge to the West CSO Diversion structure to utilize the existing outfall; it did not include additional hydraulic impacts from CSO flow contributions that theoretically could occur in the same junction within the same timeframe. The CSO sewer model calibration is currently ongoing based on data obtained from the City's 2023 metering program. This ongoing calibration of the sewer model does not hinder the drainage analysis, which is a separate model (described in Section 4).



Legend

- Mainline Conduit (Phase 1)
- Branch Drain (Phase 2)
- Existing Drain
- 2000 HB PDR Area
- West CSO Diversion Station

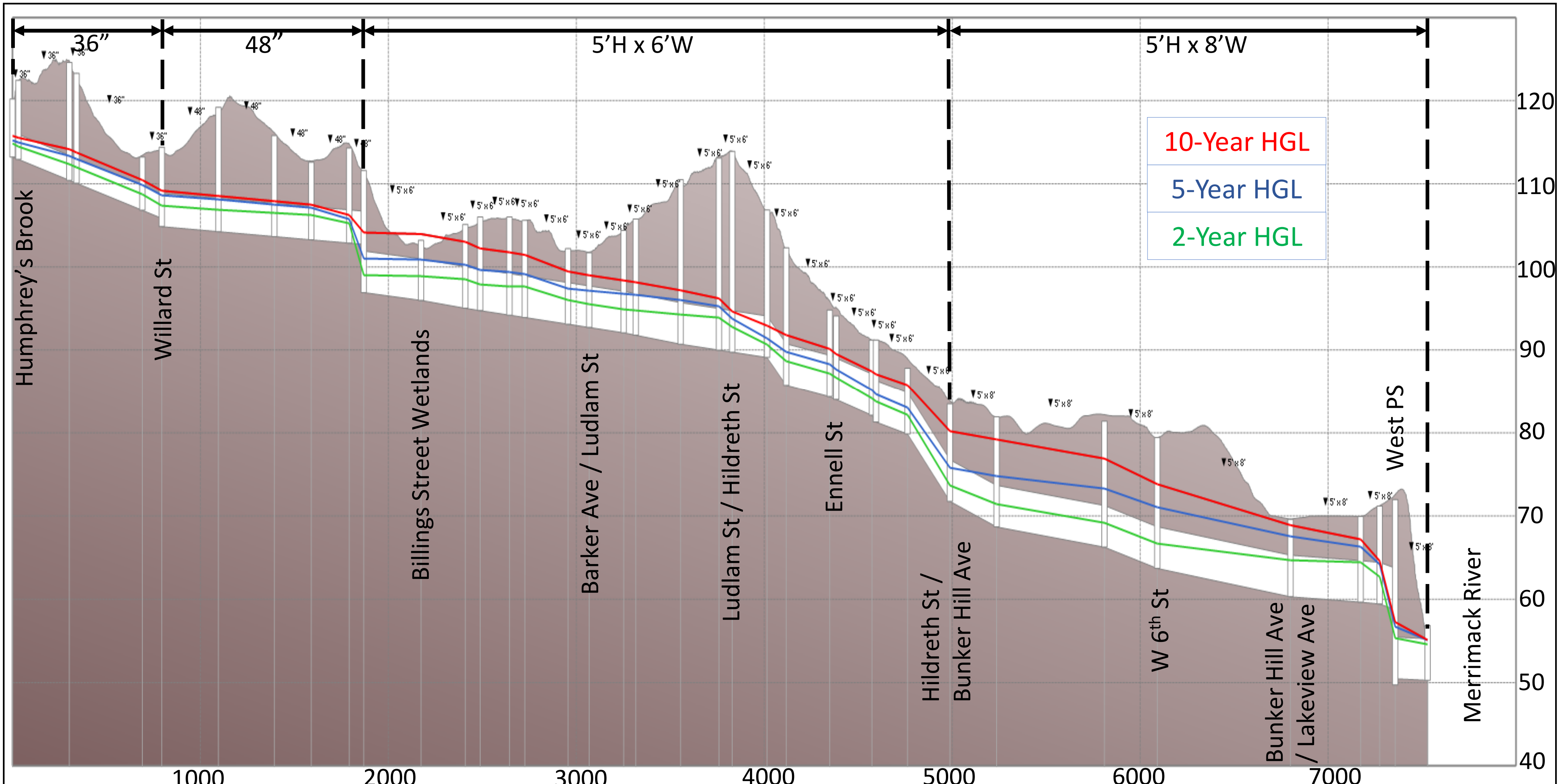
Separation Areas (Phase)

- Methuen (2A)
- Northern Branches (2B)
- Middle Branches (2C)
- Bunker Hill Ave (2D)
- West/Coburn/Jewett (2D)
- Upper Jewett/Hampshire (2E)

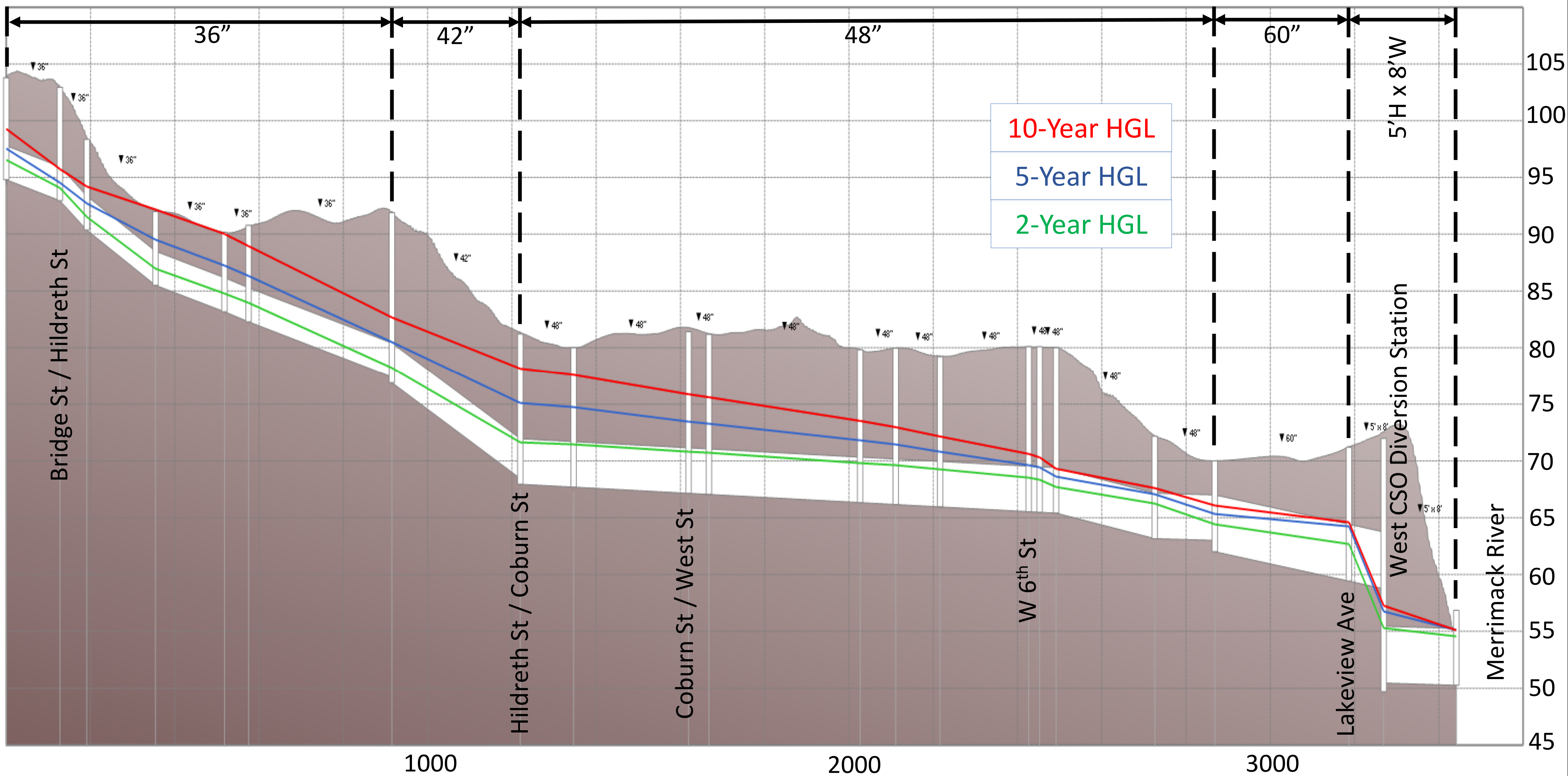
Lowell, Massachusetts
Centralville Sewer Separation PDR

Figure 6.4

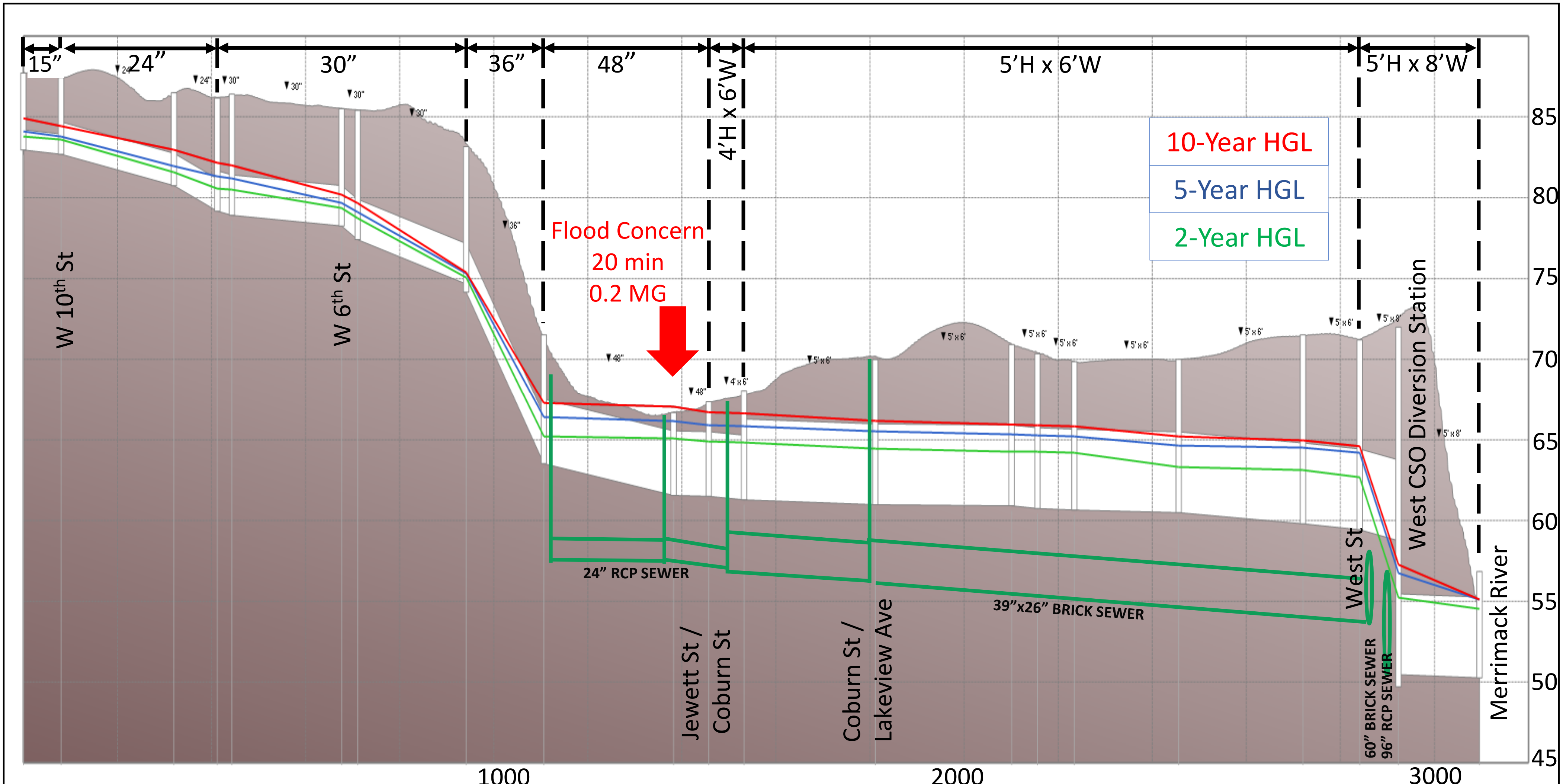
Connecting to West CSO Diversion Station



Lowell, Massachusetts
Centralville Sewer Separation PDR
Figure 6.5
Peak Hydraulic Grade Line Profile for Mainline to West CSO Diversion Station



Lowell, Massachusetts
Centralville Sewer Separation PDR
Figure 6.6
Peak Hydraulic Grade Line Profile for West Street



Lowell, Massachusetts
Centralville Sewer Separation PDR
Figure 6.7
Peak Hydraulic Grade Line Profile for Lakeview Avenue, Coburn Street, Jewett Street

Figure 6.5 presents the peak hydraulic grade line profile for the mainline to West CSO Diversion Station. The pipe sizes range from 36-inch to 48-inch moving from Humphrey's Brook to the Billings Street Wetlands, where it increases to a 5-foot by 6-foot box culvert because, there is less basin damping effects from this wetland compared to the larger, less developed Humphrey's Brook basin. The large box culvert continues south, collecting additional separation area and increases to a 5-foot by 8-foot box culvert along Bunker Hill Avenue to the West CSO Diversion station. The profile indicates sufficient capacity in the mainline for 2- and 5-Year Storm events; however, during a 10-Year storm, the mainline would flood at the Billings Street Wetlands Area and have significant surcharging in Bunker Hill from Hildreth Street to the West CSO Diversion Station. The Billings Street Wetlands flooding can be isolated to the wetlands, where it can be attenuated, if no other catch basins are connected in this same low area.

There are also other hydraulic and operational concerns with increasing conveyance capacity and connecting to West CSO Diversion Station. These concerns are described in the constructability challenges subsection.

Figure 6.6 presents the Peak Hydraulic Grade Line Profile for West Street, which conveys the middle and some of the southern separation areas with required pipe sizes for a 5-year design storm ranging from 36-inches to 60-inches in diameter closest to the West CSO Diversion Station. The impacts of the culmination of the flows from all the networks at Lakeview Avenue, plus the transition from steeper networks to flatter networks, causes significant surcharging to propagate upstream.

The largest impacts to low laying areas are presented in **Figure 6.7** which shows the shallow, large diameter pipe along Lakeview Avenue, Coburn Street, and Jewett Street. Due to the combination of the local separation area transitioning from steep slopes to extremely flat slopes following topography, meeting targeted elevations to cross existing larger diameter sewers, and the significant influence of flows culminating under similar profile conditions, this requires larger pipe sizes to compensate for the capacity issues. The result is over 1500 linear feet of a 5-foot by 6-foot box culvert to meet the 5-year design storm criteria, which is the same size as the main conduit with significantly more flow. However, during a 10-year storm event, there is a risk of flooding (0.2 mg for 20-minutes) on a street that does not report any flooding today. Despite being smaller in size , a key characteristic of the existing CSS is that the entire sewer system is a minimum of 5-feet lower in elevation at Jewett Street compared to the new drain so, during larger storm events, it can surcharge higher without flooding. The approximate depths of the sewers are shown on the profile for reference. The new stormwater system cannot be lowered due to conflicts with the existing sewers and river elevation impacts. Subsequent alternative simulations that remove the influence of the inflow sources mainline conduit (Section 6.6.4) found that the removal helps reduce pipe sizes, but does not completely resolve the flooding risk. It may be prudent to investigate reducing the flow that is separated upstream of this area since it sends flows from steeper roads to this flat spot (Section 6.6.5).

6.6.3.3 Constructability Challenges

Hydraulic Considerations

This alternative makes use of the existing West Street Pump Station infrastructure. However, this must be weighed against several hydraulic disadvantages, including:

- conveying larger flows to the station since the new two-pipe system (sewer vs stormwater) increases conveyance capacity downstream compared to the existing one pipe combined system.
- additional conveyance capacity of the separated system overwhelming the West Street Pump Station rated capacity. A separate outfall for the brook removal (rather than a shared outfall) would be preferred.
- constructing new infrastructure over the 96-inch interceptor and connecting to the West Street CSO Diversion Structure.
- larger size of the Lakeview Ave box culverts and the potential for surcharging.
- The challenge of CSO reporting as additional metering would be needed to discount the stormwater portion of the combined outfall discharge.

Increasing the conveyance capacity with a two-pipe system creates a significant concern with overwhelming the capacity of the station should pumping be required to evacuate all the combined flow from the stormwater and combined sewer systems. Early simulations of only the stormwater component suggest that all the drainage connected to the station could contribute flowrates up to 5 times higher than the capacity of the station during a 5-year storm if, coincidently, the river elevation is high enough to require pumped discharges. Consequently, the lower areas adjacent to Lakeview Avenue would flood, which is what the pump station is intended to prevent. Early simulations also indicate that removing the mainline conduit from the station reduces the flooding risk by about 50 percent. This analysis is subjective without adding the combined sewer control components for CSO mitigation and other groundwater, river, and coincidental storm considerations; however it is apparent that a separate outfall for the mainline conduit is needed and this requirement was incorporated into subsequent alternatives.

Even with reducing the separation area contributed to the West CSO Diversion station, there will need to be modifications for how the station operates if a connection is made. The Utility is required by the EPA to report the volume of CSOs that exits the station. Currently, a gate dictates when flow is to come into the diversion structure/station and any flow that passes the gate can be measured by an ultra-sonic sensor. Otherwise, all flow goes to Duck Island. With the new connection, flow will be constantly coming out of the culvert and into the diversion structure. This flow will only be drainage flow and therefore does not need to be measured or reported during dry weather. However, this situation would be complicated during wet weather conditions when the CSO gate from the influent channel to the diversion structure is opened and CSO discharged; there would need to be a way to measure only the CSO flow and not the drainage water entering the diversion structure and subsequently the existing outfall. This may be challenging since the CSO flow and non-CSO (drainage) flow would be mixed at the outfall. During final design, further investigation would be needed to develop a flow measure system that would differentiate between the CSO and drainage flows conveyed to the outfall discharge.

Connection Challenges

West Station Diversion Structure Connection

Connecting the drainage system to West Station will require careful planning and execution. West Station is situated on the VFW Highway along the Merrimack River. The station currently is used to discharge combined sewer overflow to the Merrimack River during high flow situations. In connecting to the West station, the ability for the station to still discharge and pump out CSO needs to be maintained. In reviewing the station operation, it was determined that the east wall of the diversion chamber is a possible connection point. One of the primary considerations for connecting is to make sure that the connection to West Station is below the critical surface elevation for the proposed drains. This critical surface elevation was found to be at the intersection of Jewett and Coburn Street with an elevation of 65.62 feet based on NAVD88. Surrounding the east wall of the station, the main CSO interceptor runs with the crown of the pipe at 56.83 feet. Given these two constraints, a 5-foot wide by 6-foot box culvert would be required with 1-foot-thick walls connecting to the station at an invert elevation of 58.83 feet (see **Figures 6.8 and 6.9);** this arrangement would keep the crown of the culvert below the critical surface elevation and the bottom of the culvert one foot above the top of the interceptor. In addition to considering the elevation of the connection to the station, additional evaluation would be needed to determine how the culvert makes the connection structurally. The culvert should not be able to be placed directly on the interceptor pipe, so a support for the culvert at this crossing would be needed. Additionally, the wall where the culvert connects to the station would require structural evaluation as the structural integrity of the wall may be compromised by puncturing it with the culvert. A new wall between the interceptor and the station may be required to support these loads and avoid interrupting operation of the station. There is no dry-weather operation; however, wet weather (CSO) operations could be limited or temporarily inoperable during installation.

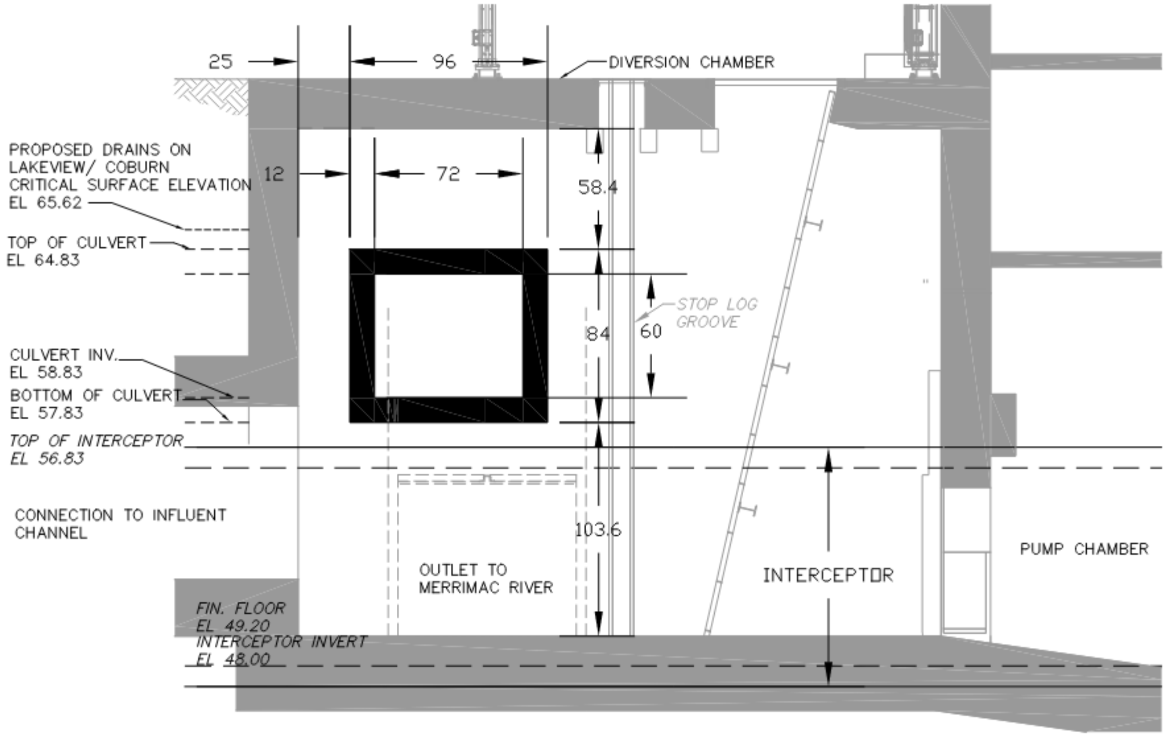


Figure 6.8 West Station Diversion Chamber Connection (East profile)

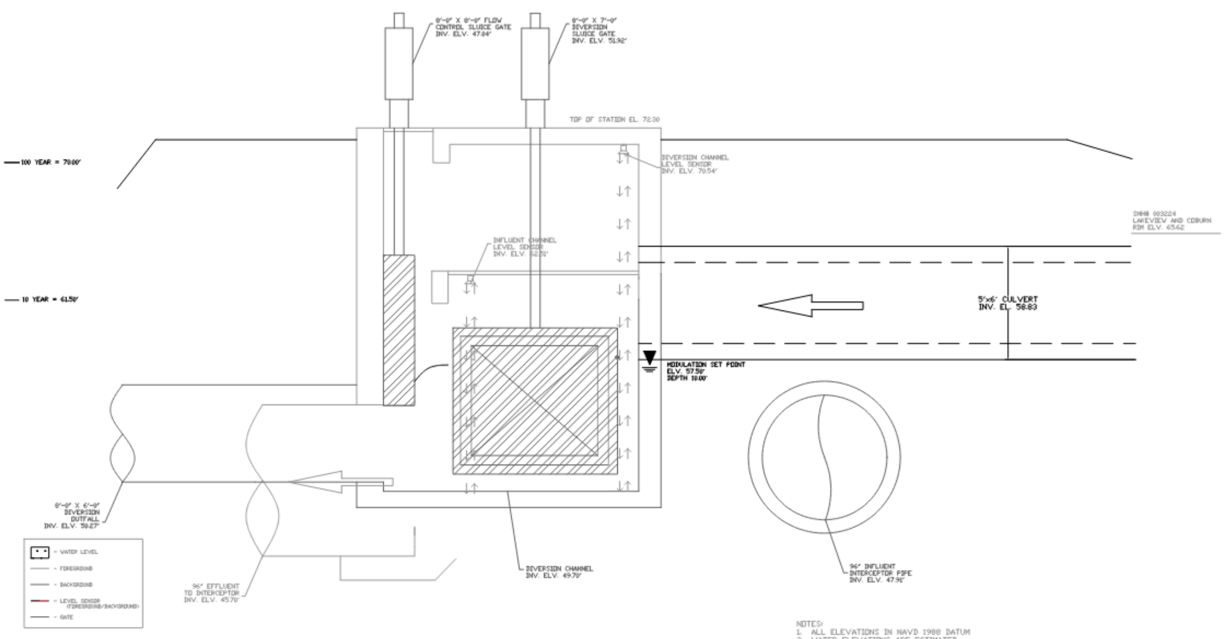


Figure 6.9 West Station Diversion Chamber Connection (South profile)

<u>West Station Outfall Direct Connection</u>

Another option for connecting to the West Station is to connect directly to the outfall conduit. This could be done by bringing the drainage culvert around the north or south side of the station (see **Figures 6.10 and 6.11**). An advantage of connecting directly to the outfall conduit is that, by leaving the diversion chamber untouched, the operation of the station does not need to be modified. The method that is currently used to measure CSO discharge from the station could still be used as the CSO and drainage water would not mix in the diversion chamber. This option would still face the same elevation challenges, as the culvert would need to cross over the top of the interceptor and stay below the critical surface elevation. Structural considerations would also need to be addressed. The culvert would need to be supported as it crosses over the top of the interceptor and the connection between the outfall conduit and the culvert would need to be reinforced. Article 97 approval is required when working within the Department of Conservation & Recreation lands along the Merrimack Riverfront. A benefit to utilizing the existing outfall is that this approach minimizes disturbance of the levee system and minimizes work in areas where an Article 97 approval is required. Work in the VFW Highway would require coordination with MassDOT.

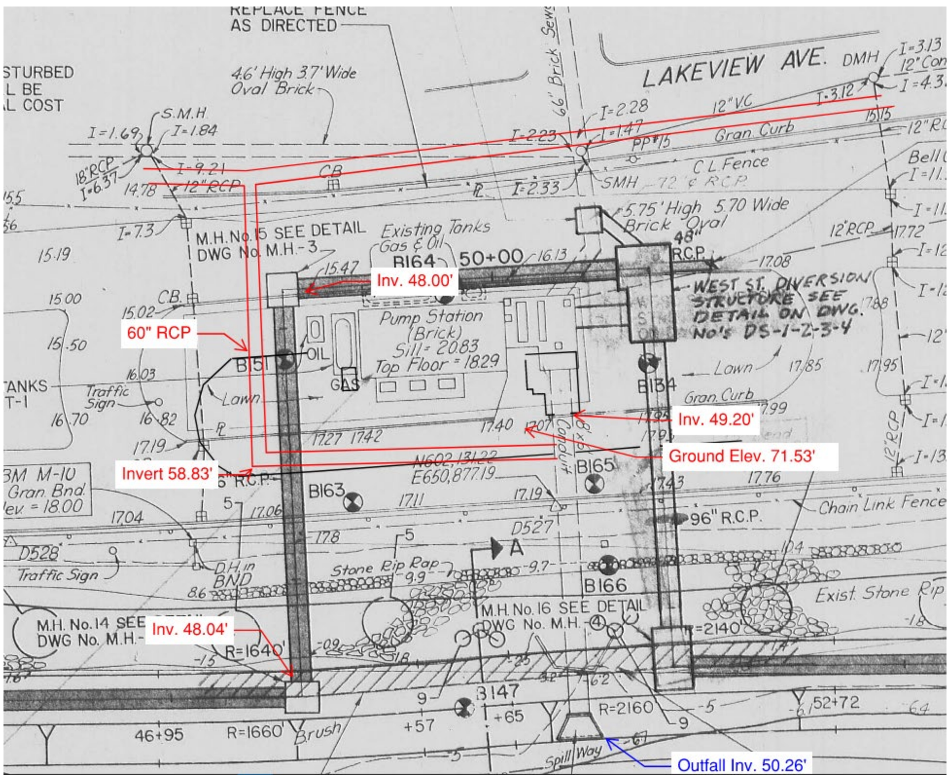


Figure 6.10 West Station Outfall Direct Connection (North Side)

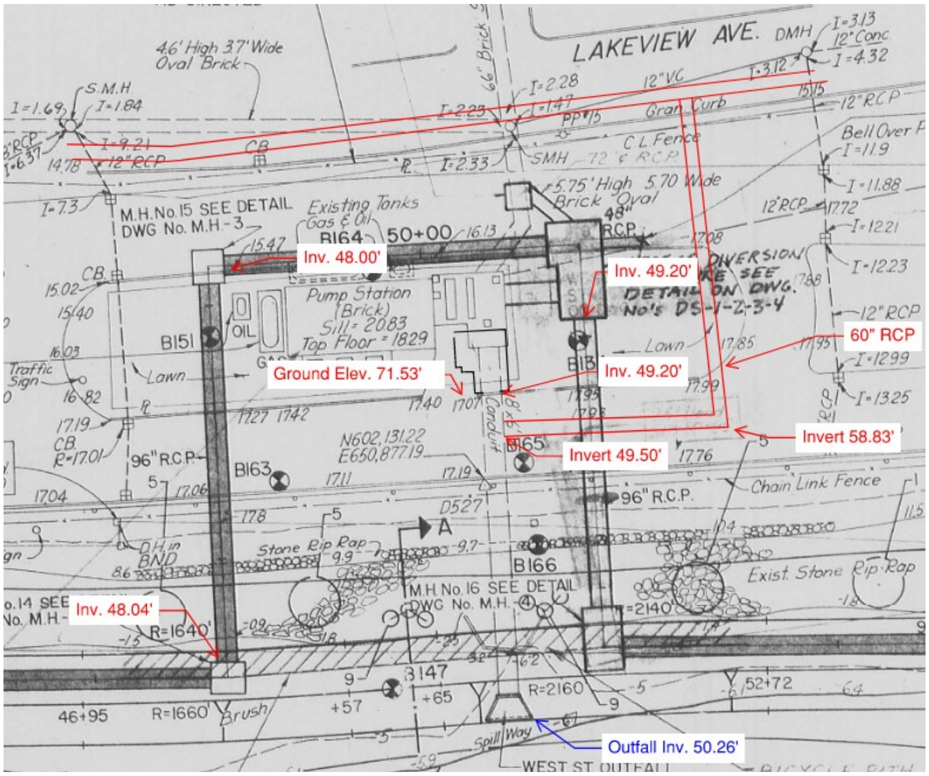


Figure 6.11 West Station Outfall Direct Connection (South side)

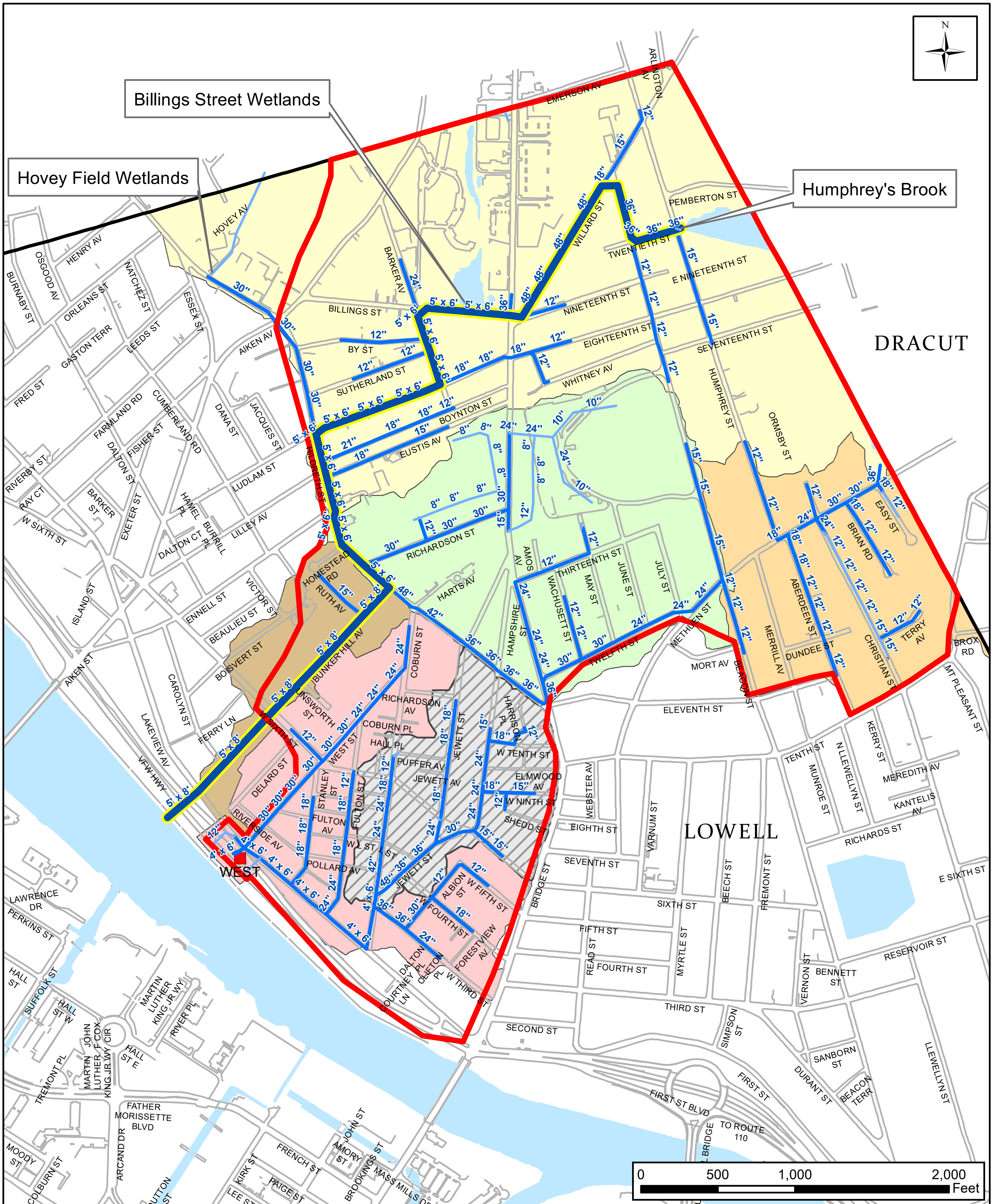
6.6.3.4 Conclusions

Because of the many challenges of routing large diameter pipes to the West CSO Diversion Station, further alternatives were developed with the goal of sending less drainage flow to the station, thereby reducing the size of the piping conveying flow to the station. Based on this evaluation of alternatives, it was clear that inflow sources, being the largest source of flow, should have a dedicated outfall to the Merrimack River, with a much smaller drainage network conveying flow to the West CSO Diversion Station. Use of a separate dedicated outfall also simplifies operations during CSO events because of the complications of accurately measuring CSO flow and stormwater flow in a combined outfall. Therefore, subsequent evaluations aimed to direct drainage flow, to the extent possible, to a separate dedicated outfall.

6.6.4 Main Conduit with Outfall Near Bunker Hill Avenue

6.6.4.1 Overview

This alternative dedicates a new outfall near Bunker Hill Avenue to discharge flows from inflow sources and future separation along the mainline conduit. **Figure 6.12** shows the main line conduit and a second network for the remaining southern half of the Centralville CSS area as described below.



Legend

- Mainline Conduit (Phase 1)
- Branch Drain (Phase 2)
- Existing Drain
- 2000 HB PDR Area
- West CSO Diversion Station

Separation Areas (Phase)

- Methuen (2A)
- Northern Branches (2B)
- Middle Branches (2C)
- Bunker Hill Ave (2D)
- West/Coburn/Jewett (2D)
- Upper Jewett/Hampshire (2E)

CDM Smith

Duck Island Lowell Regional Wastewater Utility

Lowell, Massachusetts
Centralville Sewer Separation PDR

Figure 6.12

Outfall Near Bunker Hill Ave

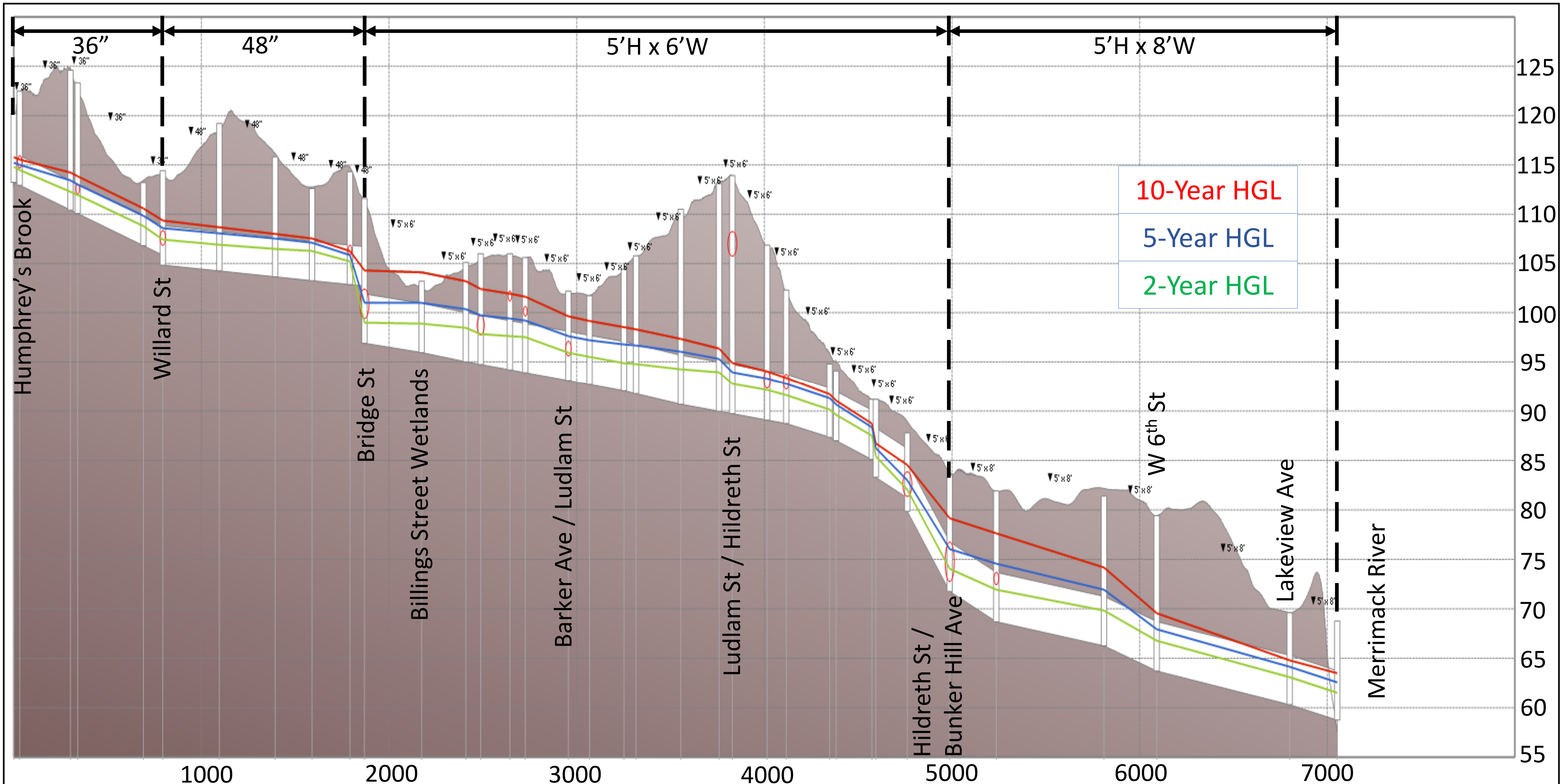
Most of the routing is similar to the 2000 HB PDR routing and the previous alternative (subsection 6.6.3.1); this route collects flow from the Humphrey's Brook and Billings Street Wetlands with the main line conduit and, traveling upstream to downstream, from the Humphrey's Brook inlet along Willard Street, Billings Street, Barker Avenue, Ludlam Street, and Hildreth Street. This alternative uses Bunker Hill Avenue to continue towards the Merrimack River at a new outfall. This drainage network would also include future separation of the northern branches, all the middle branches, and the Bunker Hill Avenue area. Based on previous hydraulic simulations, it was determined the middle branches from Hildreth Street (East) should be conveyed to the main line conduit; this avoids larger pipe sizes along West Street and sending too much flow towards Lakeview Avenue.

The remaining separation in the southern half of the Centralville CSS area would be collected with the larger trunk drains located along West Street and Lakeview Avenue. This collects future separation of the remaining lower areas shown in pink and cross gray hatched. Despite flooding risk in the low laying area, both areas were included in the hydraulic simulations of this alternative to determine the required pipe sizes along Lakeview Avenue. This alternative uses the existing outfall from West CSO Diversion Station; however a second outfall to the Merrimack River could be further investigated.

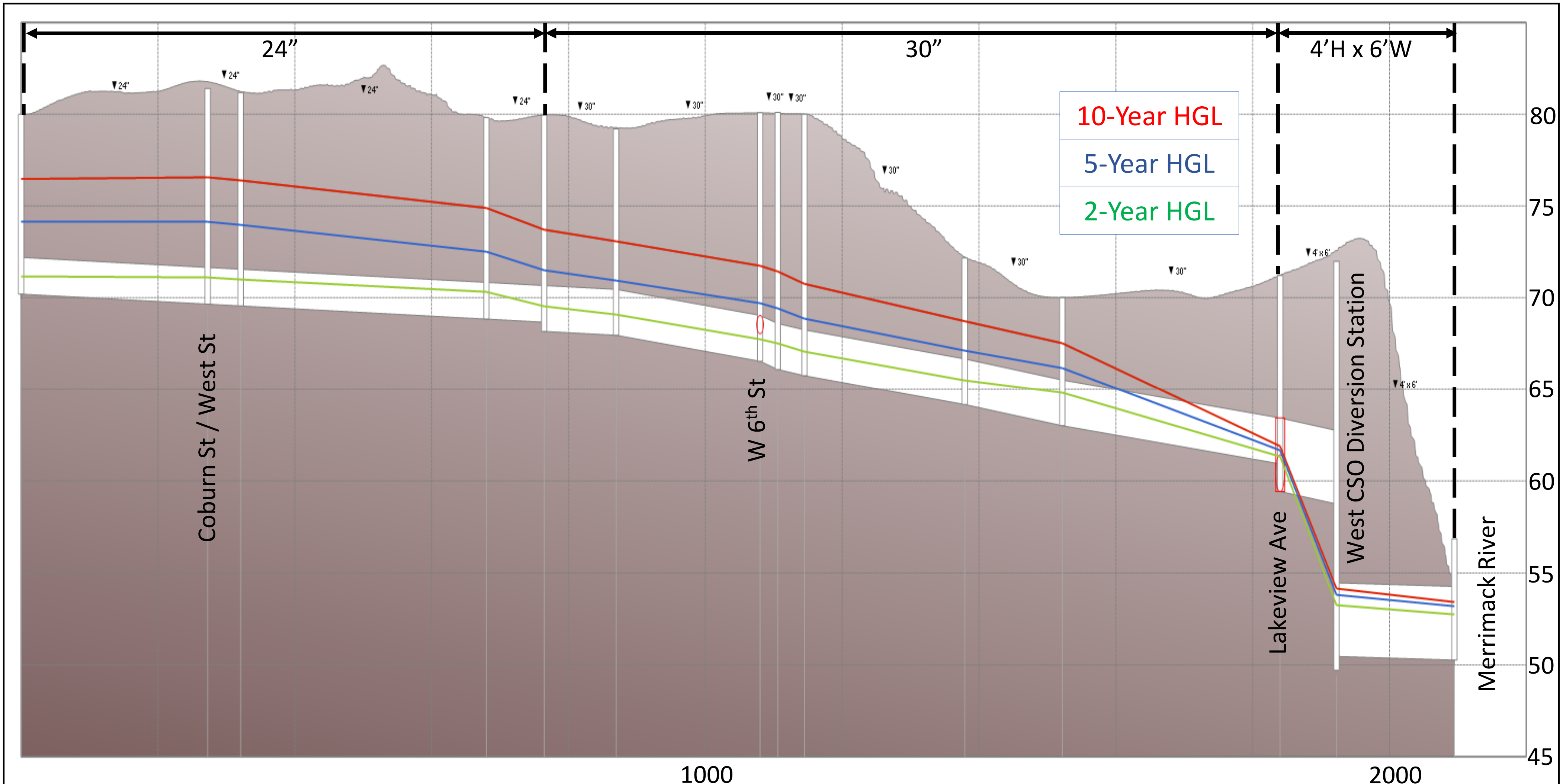
6.6.4.2 Hydraulic Modeling Simulations

Hydraulic modeling of the drainage configuration described above was used to size pipes for a minimum 5-year design storm; the model was then used to simulate 2-year, 5-year, and 10-year design storms to assess performance, particularly the 10-year design storm to minimize any temporary flooding. The profile of the three key conduits for inflow removal and separation are shown in **Figure 6.13 through Figure 6.15.** The simulations assumed free discharge of the mainline conduit to the Merrimack River near Bunker Hill Avenue and free discharge of the remaining separation areas to a second outfall, currently depicted as being connected to the West CSO Diversion station.

Figure 6.13 presents the peak hydraulic grade line profile for the mainline to outfall near Bunker Hill Avenue, which conveys the inflow sources plus additional separation in the route described in the overview. The pipe sizes are relatively the same as previous alternatives between Humphey's Brook and the Billing Street Wetlands with pipe sizes ranging from 36-inches to 48-inches; along Hildreth street between Billings Street Wetlands and Bunker Hill Ave, a 5-foot by 6-foot box culvert is required, increasing to a 5-foot by 8-foot box culvert along Bunker Hill Avenue. The only difference is that, under this alternative, the main line conduit discharges directly to the Merrimack River. This change drops the surcharging in the 10-year design storm a few feet downstream of West 6th Street below the 70-feet elevation. This is discussed further in the constructability challenges subsection.

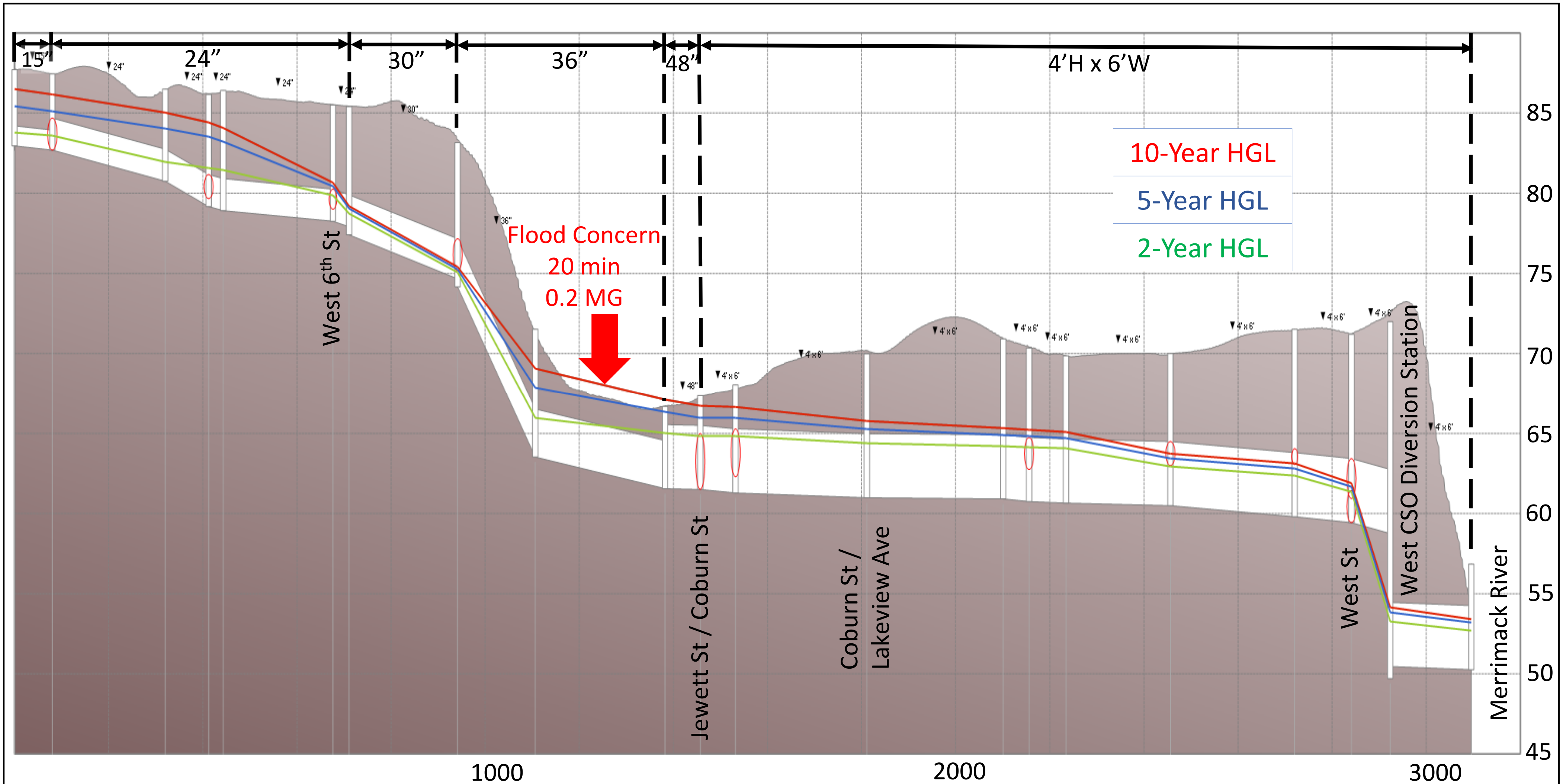


Lowell, Massachusetts
Centralville Sewer Separation PDR
Figure 6.13
Peak Hydraulic Grade Line Profile for Mainline to Outfall Near Bunker Hill Avenue



CDM Smith

Lowell, Massachusetts
Centralville Sewer Separation PDR
Figure 6.14
Peak Hydraulic Grade Line Profile for West Street



Lowell, Massachusetts
Centralville Sewer Separation PDR
Figure 6.15
Peak Hydraulic Grade Line Profile for Lakeview Avenue, Coburn Street, Jewett Street

Figure 6.14 presents peak hydraulic grade line profile for West Street which conveys a portion of the southern separation areas with the required pipe sized for 5-year design storm criteria; required pipe sizes range from 24-inches to 30-inches in diameter closest to the West CSO Diversion Station. This significant reduction in pipe size along West Street is possible by sending separation flows from the middle branches east to the mainline conduit Bunker Hill Avenue rather than south as under previous alternatives.

Figure 6.15 presents the peak hydraulic grade line profile associated with West/Coburn/Jewett and Upper Jewett/Hampshire without the mainline conduit influence. There is only a minor reduction of box culvert size to 4-foot by 6-foot compared to the previous 5-foot by 6-foot; the height was reduced instead of the width to provide an additional foot of cover and stay below the roadway subbase layer that the previous alternative encroaches into. The flood risk is still 0.2 MG for 20 minutes. This suggests that the two primary factors contributing to flooding risks in these areas are the separation of upstream areas transitioning from steep to flat topography, and the drainage network being too shallow due to downstream conflicts with existing large diameter sewers. Removing additional separation upstream is analyzed in the next alternative's simulations and solves the flooding issues (see section 6.6.5).

6.6.4.3 Constructability Challenges

As described in the overview of this alternative, most of the main line route is the same as previous alternatives from the Humphrey's Brook inlet and therefore the same constructability challenges discussed earlier. The challenges along Bunker Hill Avenue from Hildreth Street to the Merrimack River are discussed in this subsection.

The 5-foot by 8-foot main line conduit on Hildreth Street would be combined with a 48-inch future separation of the middle branches and head south. Although it is represented as a T-section with the box culvert making a 90-degree change in direction, hydraulically this corner may be made with two 45-degree bends with the 48" pipe connecting into the side at an angle to minimize head losses when the flows combine. This footprint will be impacted by the amount of available space between utilities and surface feature restrictions.

Along Bunker Hill Avenue, the profile ranges from 10- to 15-foot deep, with a wide excavation due to the conduit size being 5-foot by 6-foot. These box culvert sections would be heavy and difficult to install, even with reduced laying lengths, which impacts installation production rates. Although it may be possible to use trench boxes, some sheeting or solider pile and lagging may be required for excavation support, especially when there are multiple utility crossings.

One area that will be particularly difficult is crossing West 6th Street, where there are multiple large diameter watermains (some abandoned but still filled with water); any exposed crossing would need to be supported and protected with extreme caution as these watermains are critical water infrastructure for the north bank of the City. Coordination with Lowell Water Department would be required to develop the best approach prior to construction. Another conflict downstream of West 6th Street would be with the existing small diameter sewers, where the elevation of the new box culvert would be the same as existing sewer services; resolving this conflict would require building a new, second lateral sewer within the same trench to later cross under the box culvert to meet the combined system along Lakeview Avenue.

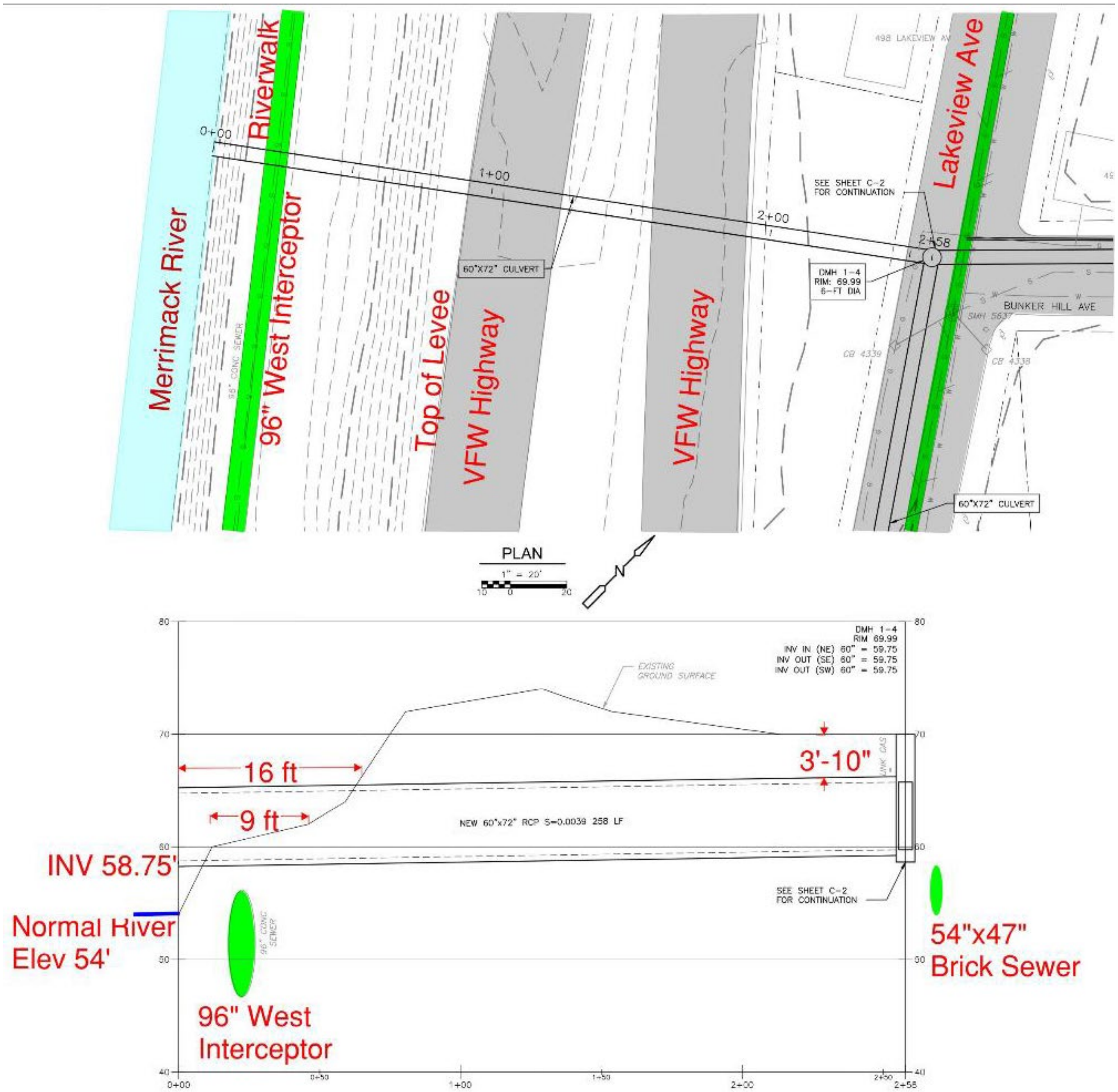


Figure 6.16 Plan and Profile, Bunker Hill Outfall at VFW Highway

Figure 6.16 shows a graphical depiction of the several construction challenges, mostly related to elevation, from the crossing at Lakeview to an outfall at the Merrimack River. These include:

- At Lakeview Avenue, there is a 54-inch by 47-inch brick combined sewer that should be lined prior to installation of the box culvert crossing over it.
- The clearance of large, combined sewers in Lakeview Avenue limits the ability to open cut as there is not enough cover to pipe jack through the levee system without ground improvements to prevent impacts to the VFW Highway. Open cut installation methods would need to be reviewed and approved by the USACE. There currently is no knowledge of any levee sheeting or reinforcement other than earthen embankment materials.

- Open cutting across VFW highway would require coordination and planning with MassDOT and the City to maintain traffic. There are two lanes in each direction and an open green mediation strip of land where lanes could be redirected during the open cut installation.
- The last segments of box culvert have two elevational challenges – (1) crossing over the existing 96-inch North Bank Interceptor (West Interceptor) with enough clearance and support on each side to prevent applying any additional force/weight directly; and (2) daylighting the top of the culvert due the steep downslope of the levee system's southern face.
- The outfall would conflict with the existing riverwalk, triggering civil site grading requirements. Any grading within the floodplain creates the need for compensatory storage requirements or a waiver from regulatory agencies. The outfall transition/apron may need to be made wider to reduce the overall height.

If the outfall were to be constructed with the invert at elevation 58.75 feet, it would be a few feet above the normal river elevation of 54-feet; however, the outfall could be submerged during the 100-year river flood stage elevation of 69-ft. Therefore, some sort of back flow prevention (either by gates or Tideflex duckbill valves) would be required. Considering the hydraulic connectivity of the local separation of the downstream area, there is a temporary flooding risk that could occur based on the additional headlosses from the river stage elevations making the most downstream segments similar to a pressure pipe application. To address this issue, all catch basin connections should have a rim elevation at least 70-feet or greater. Consequently, this means no catch basins south of West Sixth Street could be connected.

Due to the hydraulic connectivity and limited construction width between the river and the toe of the levee system, crossing under some of the elevation obstacles was conceptually considered. **Figure 6.17** shows a profile graphic that drops the box culvert another 10-feet, creating a pressure pipe/siphon which would remain full of water. Since the inflow sources will continually be conveying flows, the water will not become stagnant; however, this does create opportunity for sediment accrual, which should be minor due to upstream sediment controls at the inlets and catch basin sumps. This concept assumed a trenchless application (pending geotechnical information), but length of deep conduit can be reduced if done by open cut if only crossing under the interceptor or creating a conflict structure/outfall combination to stay below existing grades to avoid compensatory flood storage. The challenges with the outfall will need to be further advanced.

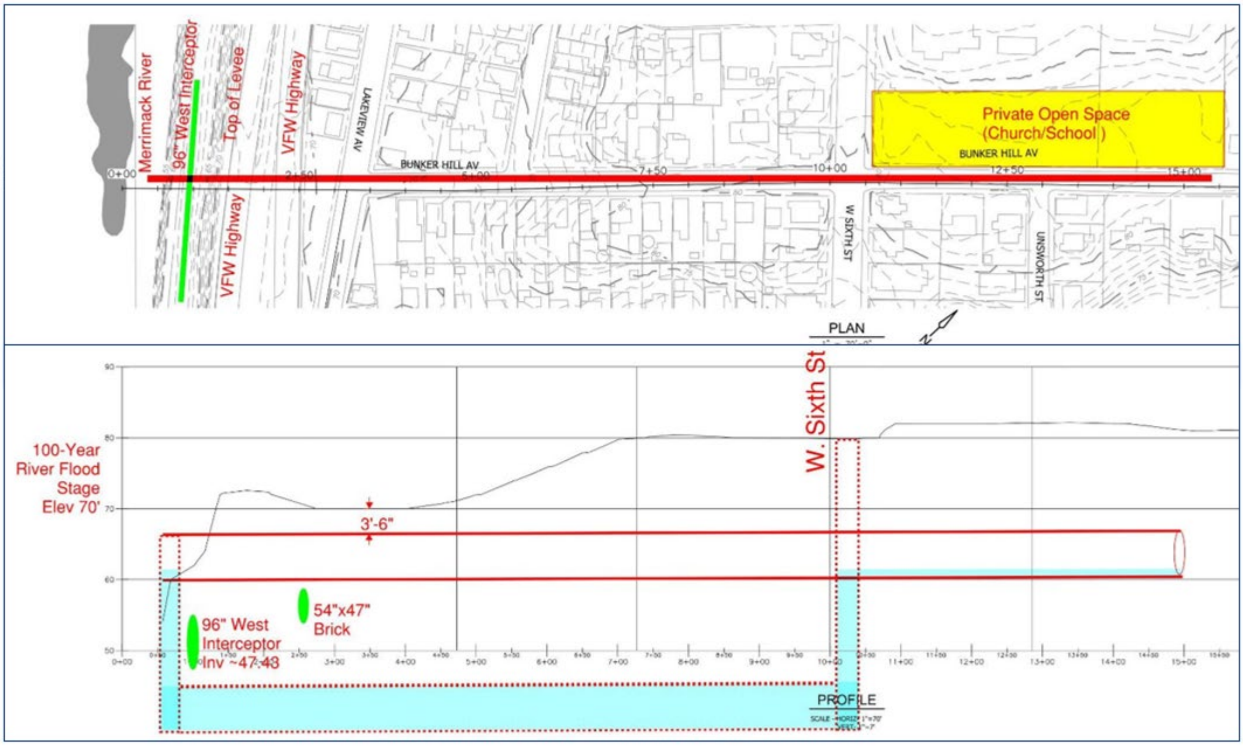


Figure 6.17 Bunker Hill Trenchless Crossing of VFW Highway

6.6.4.4 Conclusions

Given the size of the conduit from Hildreth Street to the Merrimack River, it is more favorable to route the mainline conduit down Bunker Hill Avenue rather than the narrower route of West Street from the 2000 HB PDR. This route allows the inflow sources and the majority of the separation areas to be discharged directly to the Merrimack River. This approach also downsizes the remaining pipe sizes south of Hildreth Street. Due to the hydraulic connection and the potential for a pressured system, the remaining system should be connected to its own outfall. Hydraulic model simulations for this area were based on a connection to the existing West CSO diversion station; however, this would only be considered if the new stormwater pipes could be connected to the existing outfall, downstream of the CSO diversion structure. It is likely that a new outfall may still be required, which would trigger permitting requirements with DCR, Army Corp, MassDEP, and other agencies.

Hydraulic simulation of this alternative shows that a flooding concern exists at the intersection of Lakeview Avenue, Coburn Street, and Jewett Street. The next alternative presents an option to resolve this concern by reducing the separation areas above which contribute to the problem, but still separate areas of historic complaints near Stanley Street.

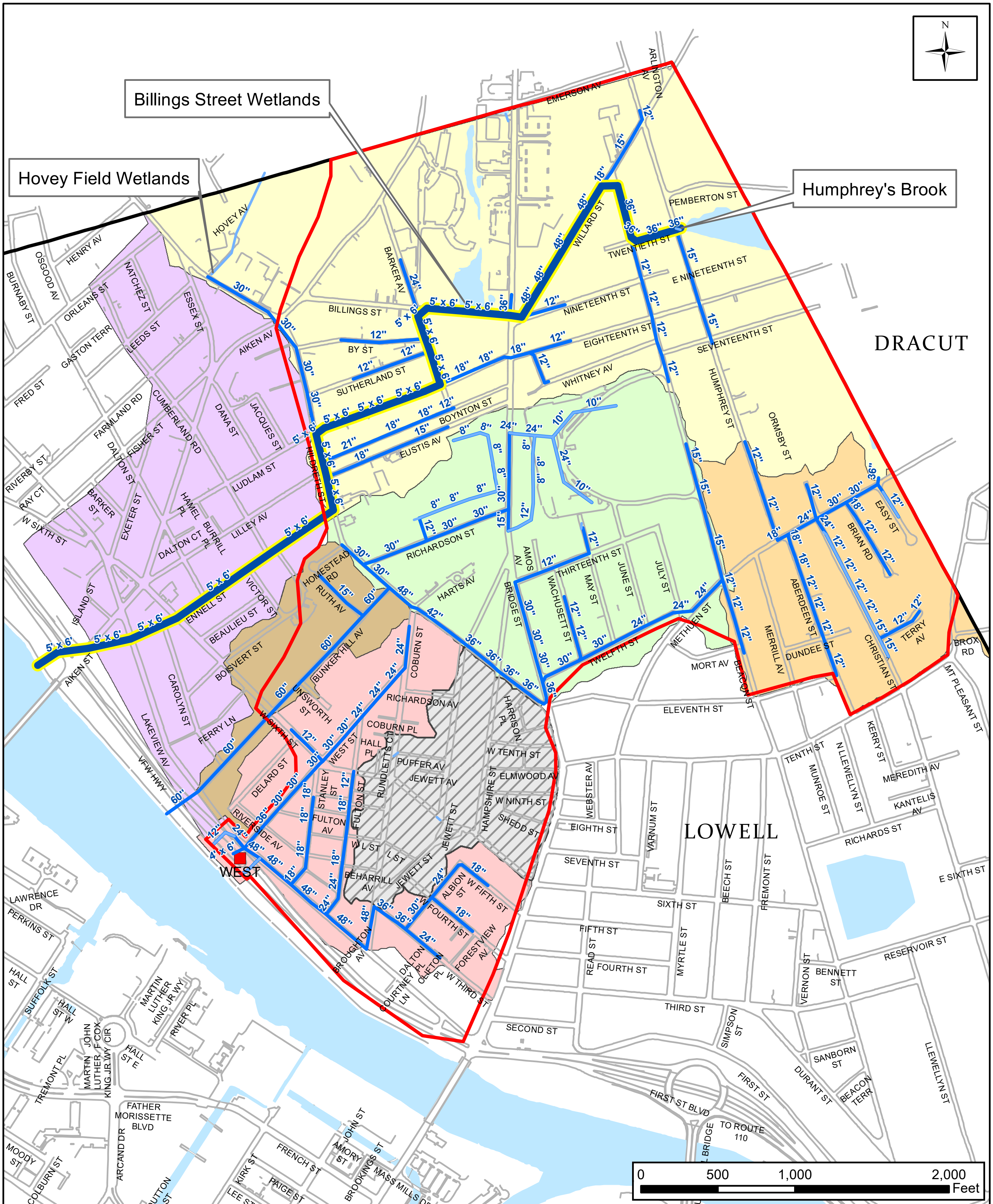
6.6.5 Main Conduit with Outfall Near Aiken Street

6.6.5.1 Overview

This alternative considers a new outfall located west of the 2000 HB PDR area to discharge flows from inflow sources directly to the Merrimack River. The advantage of this outfall location is that the outfall would not be located within the levee system, which ends at the Aiken Street Bridge. Under this alternative, the approximate length of the main conduit is 6,540 linear feet. **Figure 6.18** shows the route of a main line conduit to an outfall near Aiken Street and reconfiguration of the remaining separation in Centralville CSS area.

The upper portion of the main line conduit is the same as previous routes except for a shorter length on Hildreth Street before the route turns southwest on Ennell Street towards the Aiken Street intersection. The future separation of the northern branches is still collected; however, the revised route now provides an opportunity to separate parts of Sewer Area 40 instead. This may be a cost effective and practical exchange for the Upper Jewett Street and Hampshire Street to accomplish the same level of CSO reduction.

The remaining separation is shown in Figure 6.18 with a drainage network collecting the middle branches down Bunker Hill Avenue to a new outfall. The West, Coburn, and Jewett Street areas convey flow down to Lakeview Avenue and then east towards the new Bunker Hill Avenue outfall; this avoids connecting any new stormwater systems to West CSO Diversion Station. Further discussion of the decision to exclude some acreage in Centralville is provided under 6.6.5.2 Hydraulic Modeling Simulations.



Legend

- Mainline Conduit (Phase 1)
- Branch Drain (Phase 2)
- Existing Drain
- 2000 HB PDR Area
- West CSO Diversion Station

Separation Areas (Phase)

- Methuen (2A)
- Northern Branches (2B)
- Middle Branches (2C)
- Bunker Hill Ave (2D)
- West/Coburn/Jewett (2D)
- Upper Jewett/Hampshire (EXCLUDE)
- Sewer Area 40 (3)

CDM Smith

DUCK ISLAND
LOWELL REGIONAL WASTEWATER UTILITY

Lowell, Massachusetts
Centralville Sewer Separation PDR
Figure 6.18
Outfall Near Aiken Street

6.6.5.2 Hydraulic Modeling Simulations

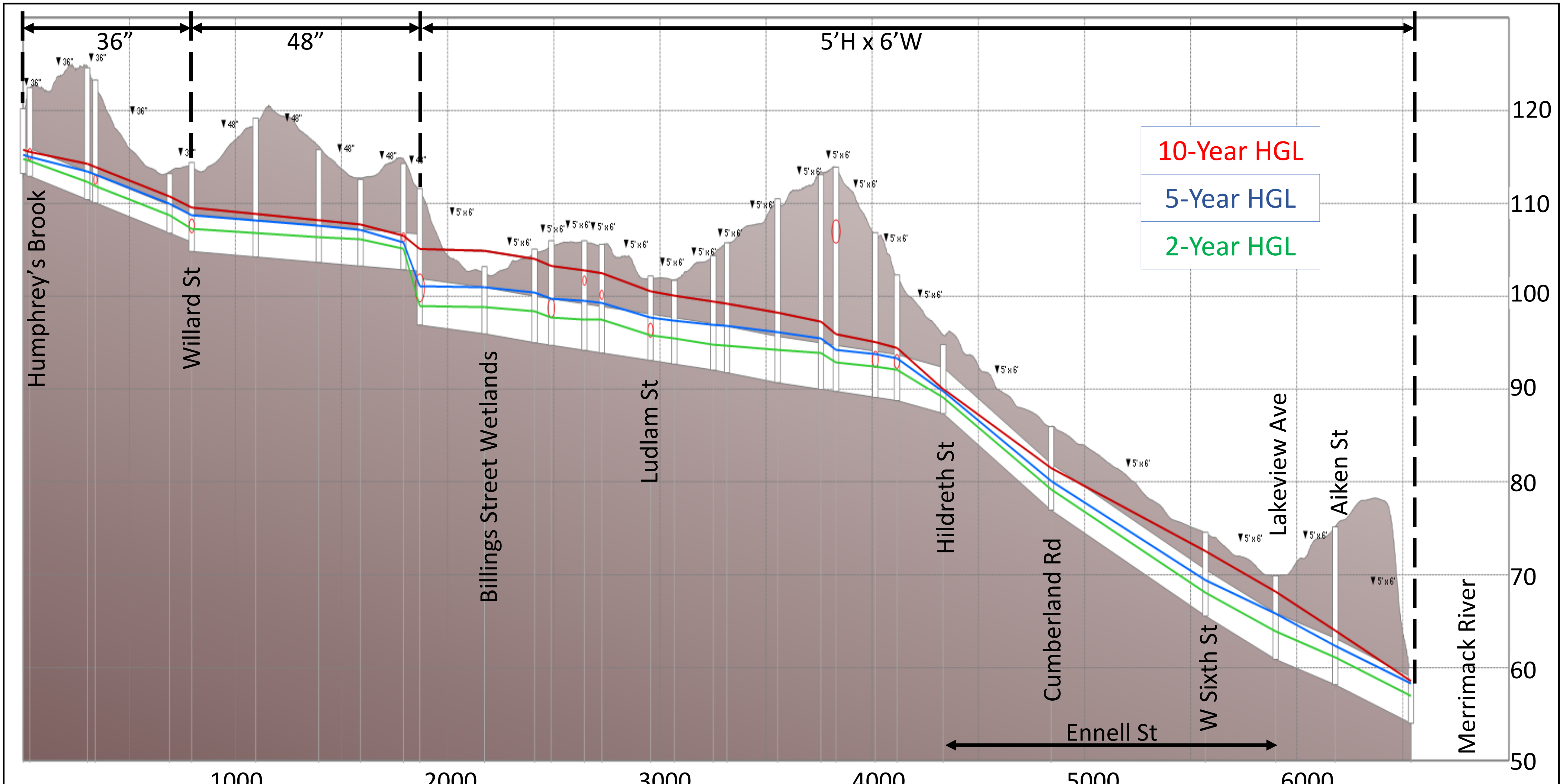
The hydraulic modeling of the drainage configuration described above was used to size the pipes for a minimum 5-year design storm; the model was then used to simulate 2-year, 5-year, and 10-year design storms to assess performance, particularly the 10-year design storm to minimize any temporary flooding. The profile of the three key conduits for inflow removal and separation are shown in **Figure 6.19 through Figure 6.22**. The simulations assumed free discharge of the main line conduit to the Merrimack River further west near Aiken Street and free discharge of the remaining Centralville separation areas to a second outfall, currently depicted as being connected to the West CSO Diversion Station. The simulations exclude the upper Jewett Street and Hampshire Street area to confirm hydraulic issues downstream caused by separation this area. Alternatively, the main line conduit with an outfall near Aiken Street has been sized for the potential future separation of Sewer Area 40 to accomplish similar CSO reduction.

Figure 6.19 presents the peak hydraulic grade line profile for the main line to an outfall near Aiken Street. The pipe has also been sized to accept future separation within Sewer Area 40. The pipe sizes are approximately the same as shown for previous alternatives between Humphey's Brook and Billing Street Wetlands, with pipe sizes ranging from 36-inches to 48-inches along Hildreth Street between Billings Street Wetlands and Bunker Hill Avenue being a 5-foot by 6-foot box culvert, and when turning west along Ennell Street toward the outfall near Aiken Street remains a 5-foot by 6-foot box culvert. Because the pipe matches the relatively steeper slope of the topography, there hydraulic benefits compared to the other routes. The pipe capacity is increased with the 10-year HGL staying below the crown of the pipe (Bunker Hill Avenue has significant surcharging); in particularly, no surcharging occurs in the low laying area near the intersection of Ennell Street and Lakeview Avenue. Separation of this intersection would be beneficial as there have been past complaints in the area; however, there are still concerns with river stage influences and the need for backflow prevention. This does not eliminate the risk of flooding at this intersection at a 100-year river elevation of 69-feet with a coincidental storm event.

Figure 6.20 presents the peak hydraulic grade line profile for Bunker Hill Avenue with a 60-inch pipe that collects the future separation from the middle branches and Bunker Hill Avenue and conveys it to a separate outfall at the Merrimack River for this network. Note there parks and green space in the middle branch separation areas, so further optimization of the pipe sizes may be possible in combination with other green solutions or attenuation to reduce pipe size even more.

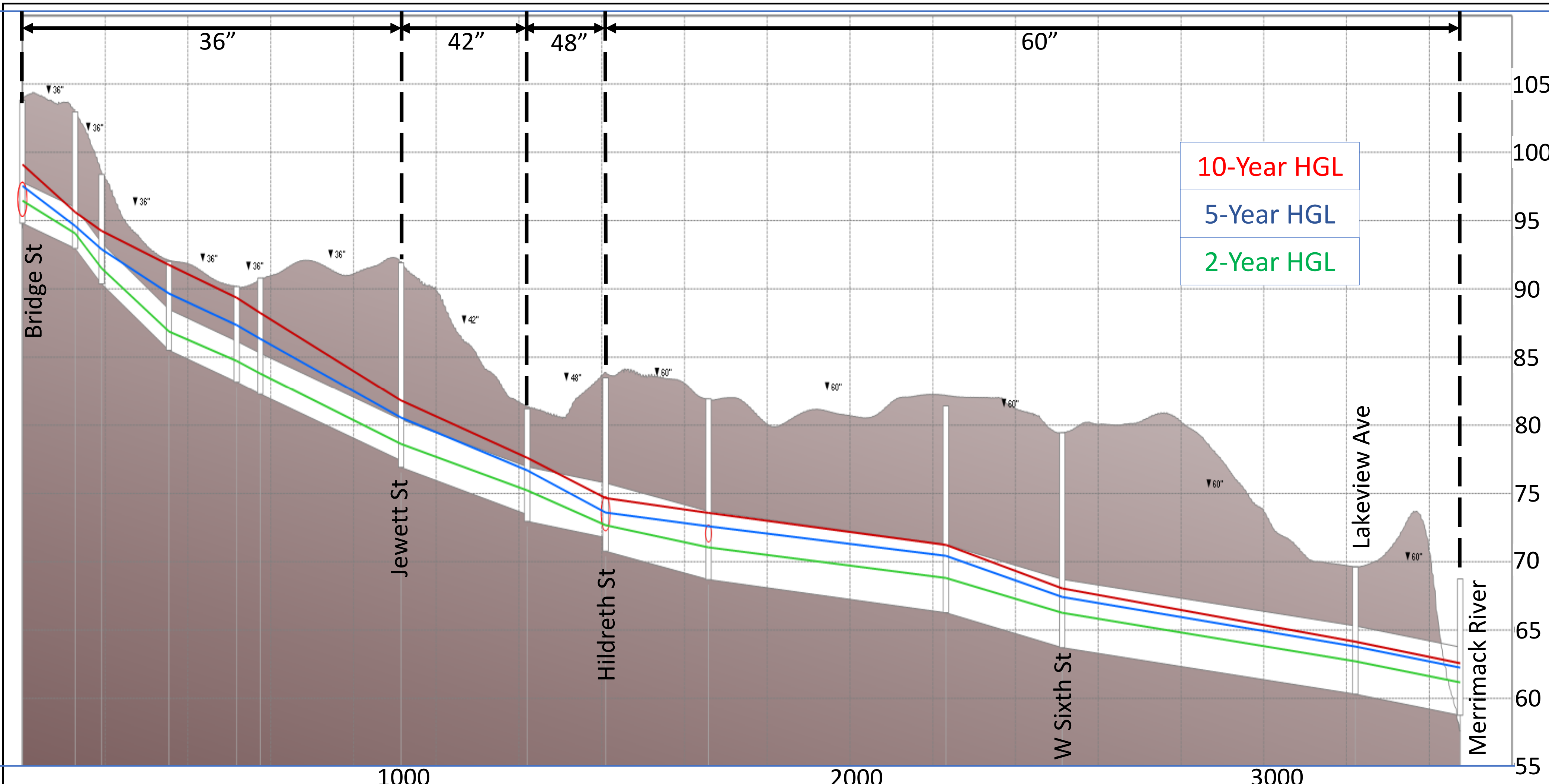
Figure 6.21 presents the peak hydraulic grade line profile for West Street, which conveys a portion of the southern separation areas with the required pipe sizes for 5-year design storm criteria ranging from 24-inches to 30-inches in diameter closest to the West CSO Diversion Station (similar to alternative with outfall near Bunker Hill Avenue).

Figure 6.22 presents the partial separation of the low laying areas (West/Coburn/Jewett only) without the main line conduit influence. Removing the Upper Jewett/Hampshire contributions brings the hydraulic grade line below the surface, eliminating the flooding concern. The pipe is also further reduced to a 48-inches.



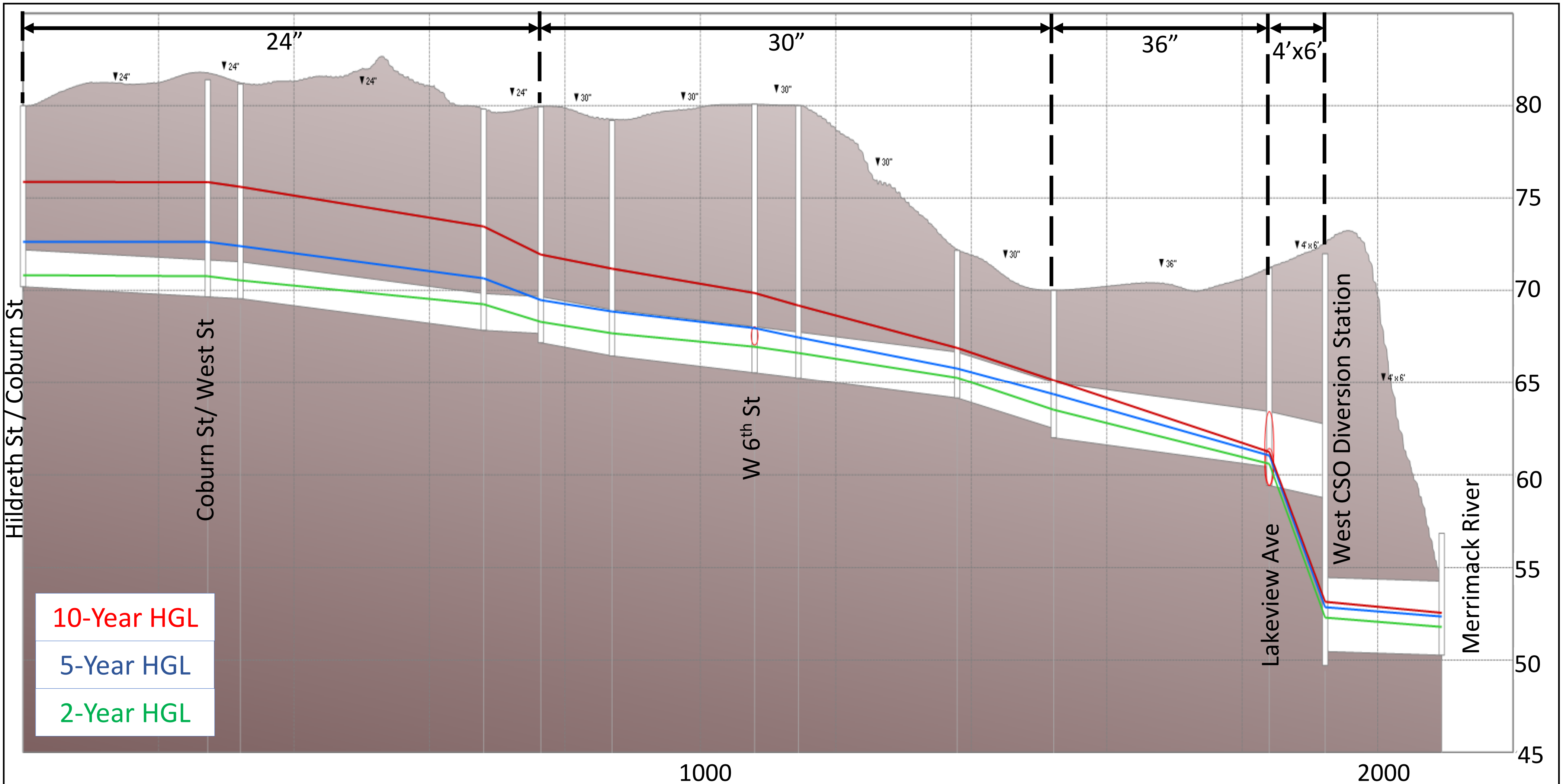
CDM Smith

Lowell, Massachusetts
Centralville Sewer Separation PDR
Figure 6.19
Peak Hydraulic Grade Line Profile for Mainline to Outfall Near Aiken Street

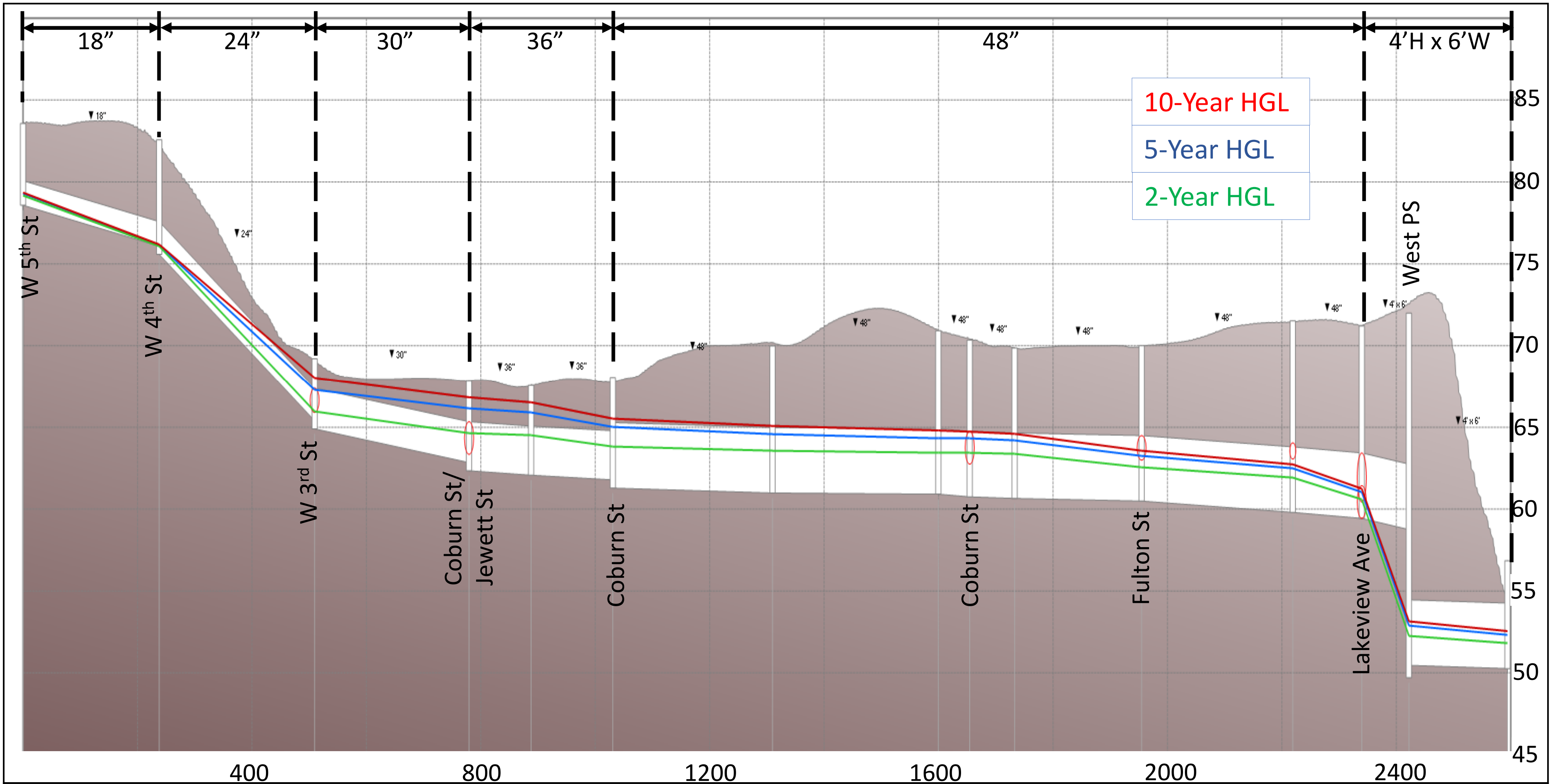


CDM Smith

Lowell, Massachusetts
Centralville Sewer Separation PDR
Figure 6.20
Peak Hydraulic Grade Line Profile for Bunker Hill Avenue



Lowell, Massachusetts
Humphrey’s Brook Preliminary Design
Figure 6.21
Peak Hydraulic Grade Line Profile for West Street



Lowell, Massachusetts
Centralville Sewer Separation PDR
Figure 6.22
Peak Hydraulic Grade Line Profile for Lakeview Avenue, Coburn Street, Albion Street

Figure 6.18 presents the reduced separation by excluding 32 acres located in the Upper Jewett Street and Hampshire Street areas upstream of the problem area, with the 5-year HGL closer to the pipe crown and no flooding in the 10-year design storm. Also, for the lower, flatter segments of Lakeview Avenue, the pipe size significantly reduces to a 48-inch pipe, which is more constructable. This simulation shows that most of the issues in this area stem from the transition of pipe networks from steep to flat which, in the existing CSS, this surcharging is absorbed by the much lower profile of the CSS where it has more freeboard to surcharge during storm events. It is our recommendation that this area be excluded.

The historic CSO model parameters of impervious versus pervious area were reviewed to indicate which may be more effective for CSO reduction and are presented in **Table 6.3.**

Table 6.3 Imperviousness of Project Area Subcatchments

Area	Acreage	% Impervious Average	% Pervious Average
Dracut	460	31	69
Methuen St	50	35	65
Northern Branches	170	51	49
Middle Branches & Bunker Hill Ave	100	52	48
West/Coburn/Jewett	50	81	19
Upper Jewett/ Hampshire	32	81	19
Sewer Area 40	86	77	23

The average percent imperviousness of the Upper Jewett/Hampshire subarea is 5 percent higher than Sewer Area 40, which means that 5 percent more of Sewer Area 40 would need to be separated to achieve relatively the same CSO reduction (approximately 35 acres). This exchange of separation areas is explained in Section 7 Alternatives analysis.

6.6.5.3 Constructability Challenges

As discussed, the upstream challenges from Humphrey's Brook and downstream of Billings Street Wetlands is relatively the same along Hildreth Street, which is one of the topographic boundaries behind the sewer areas delineation, until the mainline conduit conveys flow west at Ennell Street, outside of the 2000 HB study area, traversing through Sewer Area 40. The main reason for exploring this option is having an outfall outside the flood damage reduction system, however it still has similar challenges. At the Hildreth Street and Ennell Street intersection the mainline conduit is a 5-foot by 6-foot box culvert which is depicted as a 90-degree turn but may become multiple bends to lessen the headloss in changing flow directions.

This alternative is much deeper, averaging 20-feet, due to avoiding elevational conflicts with sewers and watermains. Despite the depth this may be better as the local sewer sizes are small within 8 to 12-inches compared to the 48 to 60-inches existing combined sewer trunk in other alternatives. This alternative has the same major elevation obstacle of crossing under multiple large diameter watermains at West

Sixth Street. The existing 48 inch brick sewer at Lakeview Avenue may be crossed under if the profile cannot be made shallower. This would likely require a sewer replacement at this crossing.

After Lakeview Avenue the topography rises making the mainline conduit go against grade and become up to nearly 30-feet deep, which makes sense as the higher ground is the reason why the levee system stops east of the Aiken Street Bridge. Extensive trench support would be required. One benefit is there is no sewer in Ennell Street from Lakeview Avenue to Aiken Street. However, the VFW Highway and Aiken Street intersection is wide and heavily trafficked so additional traffic management plans would need to be developed.

Northwest of the intersection is a fair amount of open space that could be utilized for a work zone to construct the outfall before it slopes steeply towards the Merrimack River. Depending on the results of the borings this may also be a potential launch area for a trenchless application heading west.

The outfall area presents similar challenges of being above the interceptor and below the existing riverwalk, however it appears less of the 5-foot by 6 foot culvert would exposed prior to making any height to width adjustments to minimize or avoid compensatory flood storage. Article 97 approval is required when working within the DCR lands along the Merrimack Riverfront as discussed in previous alternative

6.6.5.4 Conclusions

Although the main conduit route is brought outside the natural topography of the sewer areas and 2000 HB area it does provide some benefits and should be considered a comparable alternative with discharging the main conduit at Bunker Hill Avenue. Unfortunately, an outfall near Bunker Hill Avenue is still required for future separation of the middle branches and Bunker Hill Area. Due to similar pressure conditions that could occur along Bunker Hill Avenue from West Sixth Street to the Merrimack River it is likely the Lakeview Ave drain would need to outfall separately as well creating three outfalls in DCR lands.

However, a benefit is that there appears to be more land available for the main conduit outfall construction, less involved grading for compensatory storage, and sets up sewer area 40 for future separation in exchange for not separating small areas of Upper Jewett and Hampshire.

6.7 Alternatives Development Conclusions

The following conclusions were reached through this alternative development section:

- Wholistic reuse of the combined sewer converted to a sewer system and building a new stormwater system is preferred. Still, there may be some cases on individual streets where further considerations will be made in the future separation areas
- The Methuen Steet drainage area will be a new stormwater system that will discharge to the existing Easy Street headwall location with potential minor modifications.
- The inflow sources require its own outfall and should not be connected to the West CSO Diversion Station structure or outfall to preserve its purpose of protecting the low laying areas behind the levee system.

- Some reduced separation may utilize the existing West CSO Diversion Station outfall.
- All alternatives will require coordination with MassDOT for crossing the VFW Highway, USACE for crossing through the levee system, and other permitting agencies such as MassDEP, DCR, and City conservation commissions for the outfalls along the Merrimack River.
- The main conduit route to either outfall need to be evaluated further pending field survey and borings.
- The two primary alternatives for phase 1 to remove the inflow sources are the main conduit outfall near Bunker Hill Avenue and the main conduit outfall near Aiken Street.

7.0 Alternatives Analysis

7.1 Overview

Section 6 considered four main pipe conveyance and outfall alternatives to separate the 2000 HB PDR combined sewer area. These alternatives were developed to eliminate the three large surface water inflows from the City's sewer system including Humphrey's Brook, Billings Street Wetlands, and Hovey Field Wetlands (two of which are considered priorities in the 2023 CD). In addition, the sewer separation program and pipe routing alternatives were developed to address the City's chronic problematic areas of street flooding and system surcharge including the area of Coburn and Jewett Streets and Blinkhorn Avenue and Stanley Street.

The alternatives include:

- **Stanley Street Outfall**
  - This was the original 2000 HB PDR plan. There are hydraulic and construction challenges associated with this alternative including construction along narrow streets and pipe conflicts around the West Station. The outfall would be installed in a USACE earthen flood protection levee.
- **West Station Outfall**
  - The new drainage system would be connected to the West Pump Station (part of the FDR System) to facilitate discharge of stormwater during high river level conditions. There are construction challenges associated with this option connecting to the pump station at the CSO outfall structure and pipe conflicts around the West Station.
- **Bunker Hill Outfall**
  - The drain system outfall was proposed to install a new drain pipe along a wider street and with a new outfall to the Merrimack River just upstream of the proposed Stanley Street Outfall. Similarly, the outfall would be installed in a USACE earthen flood protection levee.
  - Due to topography and potential high river conditions, the new outfall will likely have to function as a pressure conduit from West Sixth Street to the river. This precludes the connection of the low lying area bounded by Bridge Street, Hildreth Avenue, Lakeview Avenue, and Stanley Street to the pressure outfall conduit. Accordingly, the drainage from this discrete area will have to be connected to the West Pump Station via the outfall structure so that stormwater flow can be discharged either by gravity or pumped when river flow is high. This is a similar issue for the proposed Stanley Street outfall (noted above).
- **Aiken Street Outfall**
  - This drain system would convey stormwater from the upstream Dracut inflow sources along Ennell Street (to a new outfall at Aiken street) through Sewer Area 40, which is part of Centralville but not included in the 2000 HB PDR area for separation. One benefit of this route is that it allows the City to potentially address street flooding at another problematic

area near the intersection of Lakeview Avenue and Aiken/Ennell Streets. In addition, the new gravity discharge outfall may be located north west of Aiken Street, which is not along any USACE levee.

- It is important to note that under this alternative a smaller sized Bunker Hill Avenue outfall (as a second outfall pipe) would still be constructed to separate the Middle Branch subarea.

For all these alternatives, the area referenced as the Methuen Street area could be separated independently of the outfall options for the separation of the 2000 HB PDR. This is because the Methuen Street area will discharge to an existing drainage channel that ultimately is conveyed via a surface water system north to Humphrey's Brook.

System hydraulics are an important consideration in selecting a preferred alternative. SWMM analyses of these options concluded that, due to local hydraulics, one area in the lower reach of Centralville cannot readily be separated without potentially causing more surcharge and street flooding. Accordingly, this report concludes that the Upper Jewett/Hampshire area (shown in Figure 7.1, in gray cross-hatch) may have to remain as a combined sewer system.

In summary, the best option to separate the 2000 HB PDR area is to either construct the Bunker Hill Avenue outfall (**Figure 7.1**) or Aiken Street outfall (**Figure 7.2**). These options would minimize the potential construction challenges and system hydraulic complexities created by the Stanley Street Outfall option and the West Pump Station connection option.

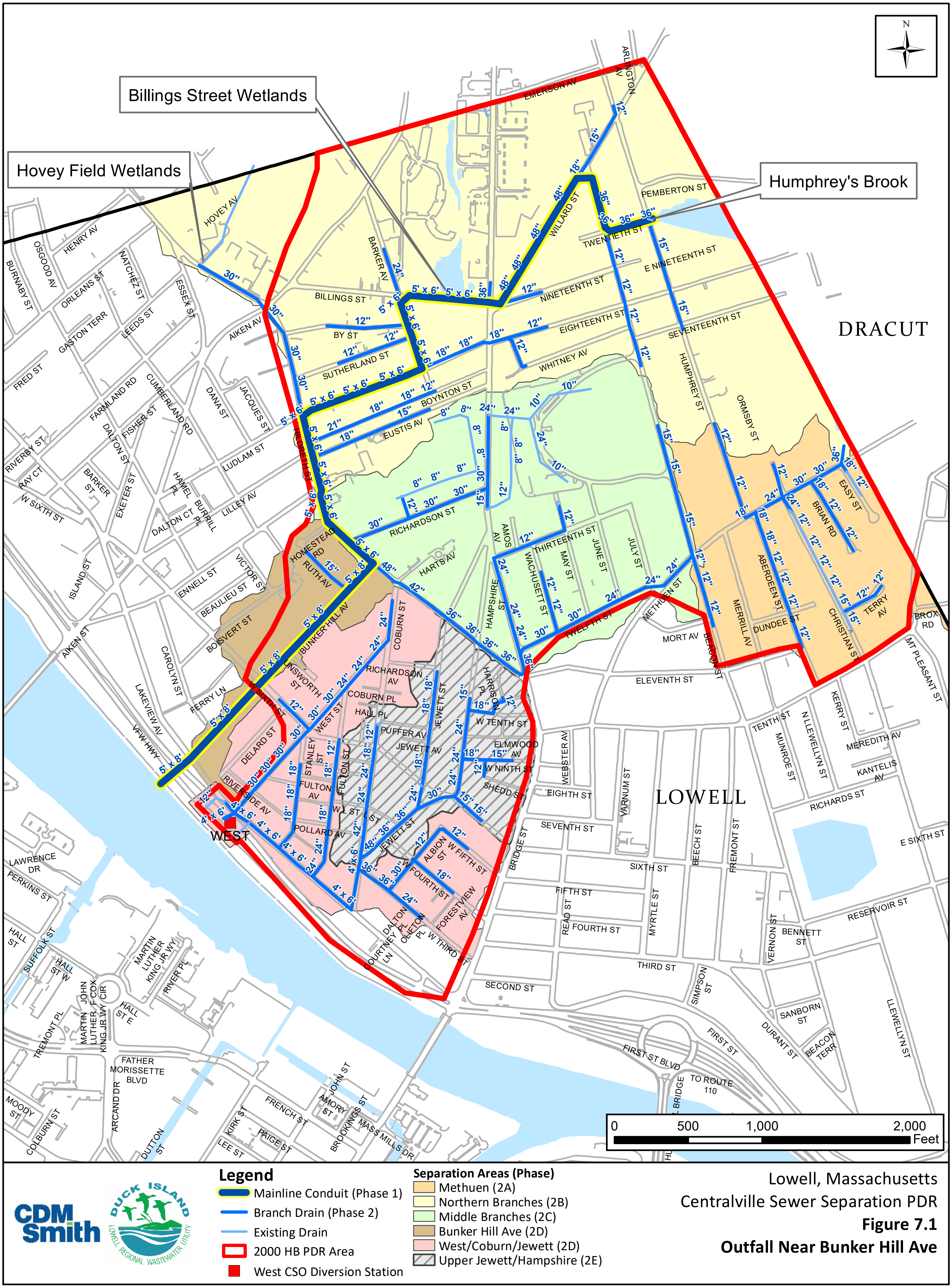
7.2 Discussion of the Most Feasible Options

As shown in **Figure 7.1** and discussed in Section 6, the study area for this PDR was separated into subbasins to identify separate drainage areas with different discharge/connection points and flow routing depending on the outfall location.

Table 7.1 lists the individual subareas of each alternative and the potential sequence of work considering that the CD identified Phase 1 as elimination of the Humphrey's Brook/Billing Street Wetland inflow sources first and Phase 2 being separation of the remaining 2000 HB PDR area. The Subareas listed in the table under each header represent the "branches" of the separation plans in each subarea that will eventually be connected to the main conduit. As noted above, the Methuen Street area will have a separate outfall and is not included in Table 7.1.

Table 7.1 Subarea Construction Phasing for the Two Most Feasible Drain Outfall Options

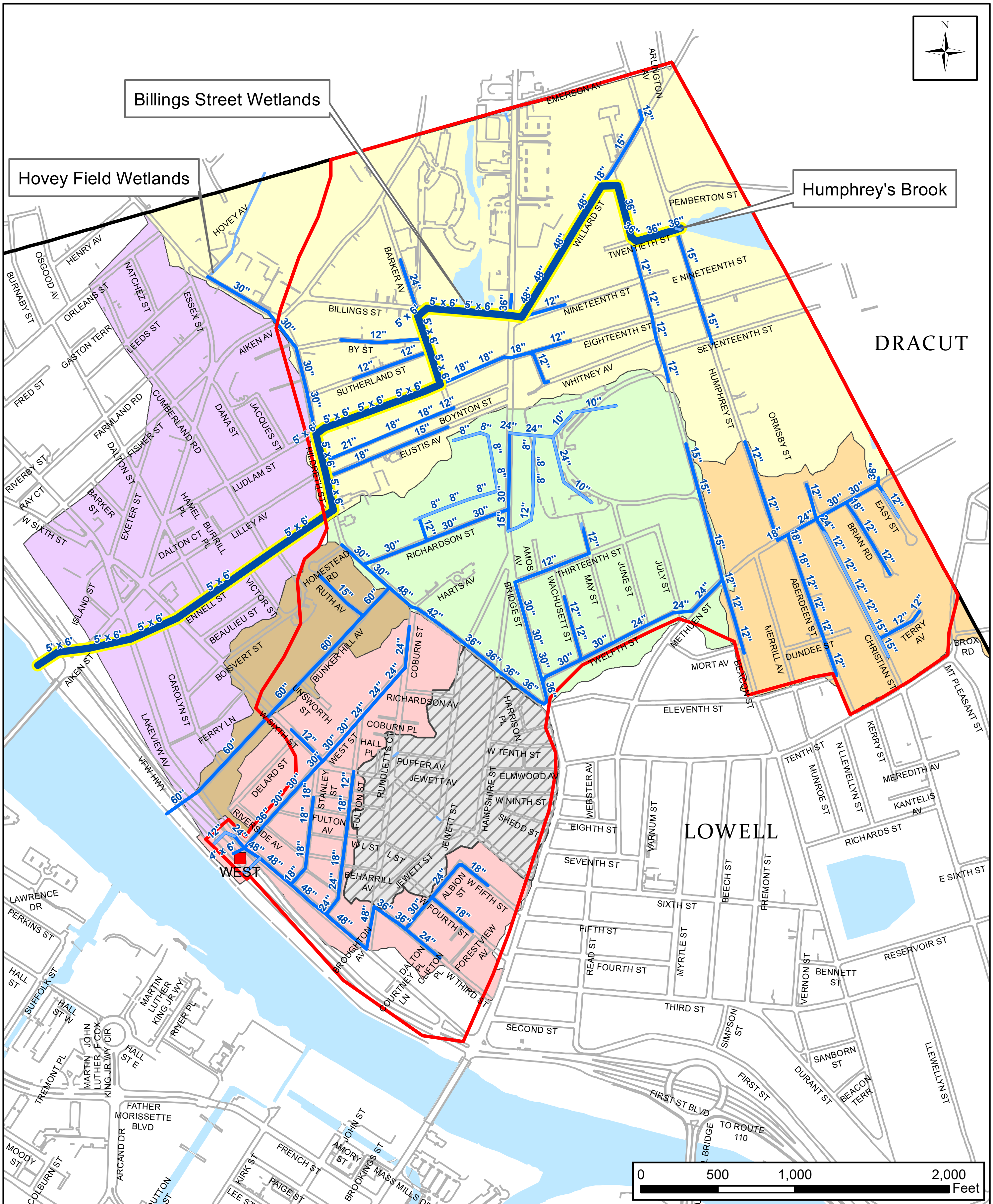
Main Conduit Outfall Near Bunker Hill Ave	Main Conduit Outfall Near Aiken St
Bunker Hill Avenue Main Conduit (Phase 1)	Aiken Street Main Conduit (Phase 1)
Northern Branches (2B) connected to Bunker Hill Outfall	Northern Branches (2B) connected to Aiken Outfall
Middle Branches (2C) connected to Bunker Hill Outfall	Middle Branches (2C) connected to Bunker Hill Second Outfall
Bunker Hill Ave (2D) connect to Bunker Hill Outfall	Bunker Hill Ave (2D) connected to Bunker Hill Second Outfall
West/Coburn/Jewett (2D) connected to West Pump Station	West/Coburn/Jewett (2D) connected to West Pump Station
Upper Jewett/Hampshire (2E) connected to West Pump Station (not proposed due to hydraulics)	Upper Jewett/Hampshire (2E) connected to West Pump Station (not proposed due to hydraulics)



Lowell, Massachusetts
Centralville Sewer Separation PDR

Figure 7.1

Outfall Near Bunker Hill Ave



Legend

- Mainline Conduit (Phase 1)
- Branch Drain (Phase 2)
- Existing Drain
- 2000 HB PDR Area
- West CSO Diversion Station

Separation Areas (Phase)

- Methuen (2A)
- Northern Branches (2B)
- Middle Branches (2C)
- Bunker Hill Ave (2D)
- West/Coburn/Jewett (2D)
- Upper Jewett/Hampshire (EXCLUDE)
- Sewer Area 40 (3)

Lowell, Massachusetts

Centralville Sewer Separation PDR

Figure 7.2

Outfall Near Aiken Street

Installation of a main drain conduit along Ennell Street to a new outfall near Aiken Street presents a unique opportunity to separate Sewer Area 40. The work to separate Sewer Area 40 should be considered as Phase 3 work, the priority of which should be also considered under the ongoing Phase 3 Preliminary Design Report and Sewer Separation Implementation Schedule (Phase 3 PDR). This is a CD requirement in Paragraph 10 to identify and prioritize the next most cost-effective CSO reduction sewer separation projects in the City to continue the system-wide sewer separation program.

Based on these two outfall options, **Volume 2** of this PDR includes a set of preliminary design plan and profile drawings that could serve as the basis for a "construction" contract for each alternative. Section 6 discusses the development of these plans using a comprehensive base map generated from existing GIS and solicited information from the other non-city utility owners in the street. These drawings are approximately at the 30 percent design level. Extensive engineering work was conducted to develop the most practical routes for new piping and determine the appropriate depth for new pipe with consideration of general constructability issues including the type of trench support, the need to minimize community impacts, and the need to minimize utility conflicts and utility relocations to the extent possible. It is important to note that this work continues to progress and the proposed pipe size/length information presented in this section is based on the hydraulic model developed for this project and may vary slightly from the pipe lengths shown on the preliminary design drawings in Volume 2.

7.3 System Size Comparison

For comparison, **Tables 7.2 and 7.3** shows the length of new drain pipe (with breakdown by size and linear feet of length and by the subareas) for the Bunker Hill Avenue and Aiken Street Outfall alternatives, respectively.

Table 7.2 Drain Statistics for Alternative 1 - Main Conduit to Bunker Hill Avenue Outfall

Pipe Size (inches/Feet)	Totals	Main Conduit	Methuen	Northern Branches	Middle Branches	Bunker Hill Ave	West/ Coburn/ Jewett
12''	8,058	-	2,386	2,980	1,771	-	921
15''	2,924	-	-	1,485	1,055	383	-
18''	3,685	-	497	1,724	-	-	1,465
21''	410	-	-	410	-	-	-
24''	3,715	-	328	383	1,528	-	1,476
30''	5,157	-	459	1,324	2,028	-	1,345
36''	2,374	794	278	136	915	-	251
42''	305	-	-	-	305	-	-
48''	1,264	1075	-	-	190	-	-
4' x 6'	1,391	-	-	-	-	-	1,391
5' x 6'	3,119	3,119	-	-	-	-	-
5' x 8'	2,065	2,065	-	-	-	-	-
Totals	**34,468**	**7,053**	**3,948**	**8,442**	**7,791**	**383**	**6,850**

Table 7.3 Drain Statistics for Alternative 2 - Main Conduit to Aiken Street Outfall

Pipe Size (inches/Feet)	Totals	Main Conduit	Methuen	Northern Branches	Middle Branches	Bunker Hill Ave	West/ Coburn/ Jewett
12"	7,549	-	2,386	2,980	1,771	-	412
15"	2,924	-	-	1,485	1,055	383	-
18"	3,923	-	4,97	1,724	-	-	1,703
21"	410	-	-	410	-	-	-
24"	3,311	-	328	383	8,52	-	1,747
30"	5,929	-	459	1,324	3,119	-	1,027
36"	2,693	794	278	136	915	-	570
42"	305	-	-	-	305	-	-
48"	2,573	1075	-	-	190	-	1,309
4' x 6'	82	-	-	-	-	-	82
60"	2,065	-	-	-	-	2,065	-
5' x 6'	4,669	4669	-	-	-	-	-
Totals	**36,433**	**6,538**	**3,948**	**8,442**	**8,206**	**2,449**	**6850**

The main conduit lengths for the two outfall options are within 10 percent but the Bunker Hill Avenue Outfall will require wider box culvert segments than the Aiken Street Outfall options at the most downstream end. Although the box culverts increase in size for the Bunker Hill Avenue Outfall, the amount of surface disruption and restoration required would be relatively the same for the two alternatives. There is some additional costs associated with deeper construction of the Aiken Street Outfall pipe along Ennell Street (refer to the design drawings included in Volume 2) because the pipe along this street requires deeper excavation and invert depth to cross under the West Sixth Street water mains and other existing combined sewer conflicts.

The two outfall plans have the same pipe size and length requirements for the Methuen Street and Northern Branches areas. The Middle Branches only differ with additional lengths of 30-inch pipe required to connect to Bunker Hill Avenue (under the Aiken Street Outfall option), whereas this stretch is part of the main conduit under the Bunker Hill Outfall option. A similar situation occurs in the Bunker Hill Avenue area, where a new secondary 60-inch outfall pipe is needed, if the Aiken Street Outfall is constructed, to convey the Middle Branches and local drainage to an outfall at the Merrimack River.

Although the total length of pipe for the West/Coburn/Jewett area is the same for the two outfall options, the size of pipe varies between the two options. Including the West/Coburn/Jewett area increases the size of downstream segments along Lakeview Avenue to a 4-foot by 6-foot culvert and does not resolve the flooding risks associated with storms greater than the 5-year design storm. This flooding issue is only resolved by excluding the Upper Jewett/Hampshire area (32 acres), which results in only a 48-inch diameter pipe being required along Lakeview Avenue.

7.4 Estimated Project Costs

An Opinion of Probable Construction Cost (OPCC) was developed based on quantities obtained from the preliminary design drawings included in Volume 2 to this PDR.

The estimate includes:

- New drain pipes and structures (inlets, outfalls, manholes) and associated installation costs (excavation and backfill).
- Surface restoration including temporary trench paving, milling, asphalt paving, limited curbing, and final full width paving.
- Limited rock removal based on available sewer record plans along the main conduit.
- Allowances for contractor mobilization/demobilization, light maintenance of traffic, and general utility relocation/offsets.
- Allowance for contractor general conditions and indirect costs.

The type of excavation support required for the main conduit and outfalls was considered based on the pipe depth, horizontal alignment, and anticipated utility impacts. These assumptions will be refined as the design progresses and additional information is obtained from the ongoing geotechnical investigation program.

Factors that influence construction costs include, but are not limited to, the following: cost of labor, materials, and equipment; services provided; schedules; contractor methods of determining prices; competitive bidding; and market or negotiating conditions. The planning level OPCCs include direct costs (materials and construction labor), indirect costs (permit fees, insurance, and bonding costs), contractor general conditions, and contractor’s overhead and profit. Additionally, construction contingencies and some escalation for future implementation are included in the OPCCs presented. These OPCCs do not include owner costs, finance or funding costs, legal fees, costs for land acquisitions or temporary/permanent easements, and permitting fees, construction oversight fees, change orders, operations, public participation costs or any other costs associated with the project that are not anticipated to be part of the bidding contractor’s proposed scope of work.

Accordingly, the following contingencies and allowances were added to the OPCC to develop a total project cost:

- Engineering and implementation costs: 20 percent
- Project Contingency: 35 percent

Tables 7.4 and 7.5 present the project cost estimates for the two outfall options, respectively. The City’s goal in developing and prioritizing projects is to target sewer separation that is cost effective and provides the greatest benefit in terms of CSO reduction. As noted previously, there are concerns that separation of the Upper Jewett/Hampshire area may increase the risk of flooding under certain conditions and it is not recommended that the City proceed with separation of this area.

The cost of the two proposed outfall options are very similar and are not a differentiating factor for the selection of the preferred alternative.

Table 7.4 Alternative 1 - Main Conduit to Bunker Hill Avenue Outfall

Description	Project Cost Subtotal ($Millions)
Separation Areas for Humphrey's Brook	
Main Conduit - Humphrey's Brook to Outfall Near Bunker Hill Ave	$44.5
Hovey Field Wetlands Connection	$4.3
Methuen	$8.4
Northern Branches	$21.2
Middle Branches	$12.6
Bunker Hill Ave	$1.1
West/Coburn/Jewett	$25.0
Upper Jewett/Hampshire	-
TOTAL	**$117.0**
Other CSO Program Components	
CSS Rehabilitation Program	$24.8
Sewer Area 40 - Branches Plus 24-to 48-inch Trunk drain	$27.3

Table 7.5 Alternative 2 - Main Conduit to Aiken Street Outfall

Description	Project Cost Subtotal ($Millions)
Separation Areas for Humphrey's Brook	
Main Conduit - Humphrey's Brook to Outfall Near Bunker Hill Ave	$44.3
Hovey Field Wetlands Connection	$4.3
Methuen	$8.4
Northern Branches	$21.2
Middle Branches	$12.9
Bunker Hill Ave	$6.0
West/Coburn/Jewett	$20.5
Upper Jewett/Hampshire	-
TOTAL	**$117.6**
Other CSO Program Components	
CSS Rehabilitation Program	$24.8
Sewer Area 40 - Branches to Main Conduit Only	$19.7

NOTES:

1 Project Costs include 20% Engineering and 35% Project Contingency.

2. Limited rock removal has been included based on available sewer records (incomplete), however more complete rock removal costs to be added based on Geotechnical Investigation Program (ongoing).

3. Costs include some general allowances for small diameter sewer relocations but do not include any watermain or private utility relocation.

4. Costs do not include bypass pumping or extensive dewatering costs, extensive traffic management plans, or any easement or land acquisition.

5. The separation of Upper Jewett/Hampshire is not recommended as described in the report sections, however the approximate cost to separate this area is approximately $14.3 Million.

6. Sewer Area 40 under Alternative 1 includes a trunk drain (24 to 48-inch) along Ennell Street required to separate the side branches. In Alternative 2 only the side branch separation is included since the main conduit box culvert is included separately.

7.5 Summary

Additional engineering work for this PDR must be completed to continue development and analysis of these two outfall options including an assessment of combined sewer system hydraulics and a determination of CSO discharge reduction benefits that could be achieved by these Centralville separation plans. SWMM analysis has been delayed due to an ongoing assessment of the flow meter data collected in Spring 2023 as part of the I/I Analysis Report, due on January 31, 2024. The data collected in Spring 2023 is not accepted at this time and is being rectified and confirmed through a series of further assessment and analysis by the flow metering company. This should be resolved soon and then the combined sewer SWMM model can be calibrated for analysis of combined sewer system hydraulics to identify CSO reduction benefits.

8.0 Implementation Schedule

8.1 Introduction

Section 6 discussed the development of pipe sizing and route alternatives to separate the Centralville CSS, including the 2000 HB PDR Area and Sewer Area 40, to remove the large inflow sources from Humphrey's Brook, the Billings Street Wetlands and Hovey Field Wetlands and to remove public inflow (and consider cost-effective removal of private inflow) from the remaining combined sewer area. Section 7 presented the opinion of probable project costs and discussed features of the two most feasible pipe route alternatives. The two alternatives will not only address the required sewer separation goals but also should address problematic and chronic street flooding in neighborhood areas along Stanley Street, Coburn Street, and Jewett Street, and near the intersection of Lakeview Avenue and Aiken Avenue.

The two pipe routes have similar construction, permitting, and public impact challenges and represent the most expansive projects the Utility has attempted in the City streets. Either route will require extensive design engineering and construction supervision to mitigate these challenges and to coordinate with the public. It is also expected that a high degree of agency coordination will be required with the USEPA, MassDEP, USACE, MassDOT, Executive Office of Energy and Environmental Affairs, and state legislators to secure the approvals to cross through areas owned and operated by these entities and to obtain an Article 97 conversion for the location of the drain pipe and outfalls along the Merrimack River.

This PDR presents an engineering approach to complete sewer separation for the 2000 HB PDR Area in a manner that meets the City's goals for sewer surcharge/street flooding and CSO reduction and the compliance requirements of the USEPA and MassDEP, and the 2023 Final CD. However, given the complexities of siting a new drainage outfall to the Merrimack River, additional engineering work is required to refine the recommended plan.

This section discusses the additional field work to be completed, workshop(s) that will be scheduled with key stakeholders, and additional engineering that will be undertaken to update this preliminary design report based on the additional information.

8.2 Challenging Conditions

Prior discussions with the regulatory agencies regarding separation of the 2000 HB PDR Area were based on the 2000 Humphrey's Brook PDR. This PDR provides a much more advanced basis for discussion that can be used to solicit initial input from the regulatory agencies.

During CD negotiations, the City clarified that the 2000 HB PDR was a conceptual study and did not consider the construction challenges associated with Lowell's FDR System. After Hurricane Katrina, the federal government and the City became more aware of the functionality and importance of these flood protection facilities after the 2000 report. Since then, the City made significant improvements to the earthen levee and concrete I-wall, and the West Pump Station (at the West Station), to make the system operable to protect the Centralville area from Merrimack River flooding. The improvements proposed in this PDR must be fully integrated with this flood protection facility to maintain its capabilities.

In addition, because of the flood protection zone, gravity discharge of stormwater into the Merrimack River from these low lying areas is a challenge. Unprotected gravity discharge of flow via an outfall pipe could allow backflow from the river during flood conditions into the low lying area. Consideration was given to use of the recently improved West Pump Station to pump out flow from the new Centralville area drain system. The approach would avoid a new gravity outfall through the earthen levee could be avoided. However, the challenge to make physical connections to the pump station and to provide a separation of CSO and stormwater flows for compliance monitoring purposes was too great a cost. In addition, the City did not want to impact the potential flood pump capacity of the existing station with the conveyance of more flow. Accordingly, the alternatives development focused on the construction of one or two gravity stormwater discharges for the new system.

The hydraulic analysis also showed that separation of some of the low lying areas, protected by the Flood Damage Reduction System, may not be practical. The existing CSS is lower than the proposed new drain and can operate under surcharge to convey wet weather flow to the North Bank Interceptor (or to the West Pump Station). It is not practical to lower the drain below the combined sewer. Accordingly, in this report, the City is proposing to keep the Upper Jewett/Hampshire subarea of the Centralville project area as a combined sewer to protect these streets from flooding during high river flood conditions.

There are many remaining hydraulic and engineering challenges in this project that require further discussion with the regulatory agencies to select a recommended approach. The City met with MassDEP to present and preliminarily discuss these issues during a November 14, 2023 workshop. At this meeting, MassDEP suggested that the report be completed to provide documentation and discussion of these issues so that MassDEP and USEPA could provide additional input. Another workshop should be scheduled to discuss the alternatives in further detail with both agencies. This approach and other follow-up activities are described in Section 8.3.

8.3 Next Steps

The City proposes to continue engineering activities to refine the sewer separation plan described in this PDR and select an outfall discharge alternative, and to advance the permitting and final design of the Phase 1 project to meet the CD milestones.

These engineering and coordination activities will include:

- An initial workshop meeting in January 2024 with the USEPA and MassDEP to discuss the conclusions of the draft Centralville Sewer Separation PDR with a follow-up meeting to finalize the discussion after the additional information (discussed below) is collected and analyzed,
- A topographic and utility survey of the major pipeline routes, with the survey scheduled for completion in February 2024,
- A geotechnical program that is underway along both routes that will be completed in February 2024,

- A meeting with Massachusetts Environmental Protection Agency (MEPA) to initiate discussions about the overall project and its incorporation into the MEPA process without an approved LTCP,
- Further development of permitting requirements and a construction approach for a new outfall through an existing flood protection levee including discussions with USACE for a Notice of Project Change and Section 408 application for modifications to a levee system,
- A discussion with the Department of Conservation and Recreation for a potential Article 97 conversion for the work through state parkland near the outfalls and riverbank,
- A meeting with MassDOT to begin discussions regarding the installation of the large diameter outfall pipe under VFW Highway and to discuss the MassDOT's current plan to separate out its own outfalls along VFW Highway at the intersection of Aiken Street,
- Meeting(s) with internal City Departments to consider integration of the sewer separation work with other City initiatives for infrastructure renewal at key milestones,
- Public meeting(s) with the Centralville Neighborhood Association to present the sewer separation and collect input at key milestones.
- Integration of the results of the City's I/I Analysis Report, due on January 31, 2024, that will provide critical information on and characterization of the amount of extraneous flow in the Centralville project area and could determine the extent sewer rehabilitation required to address I/I mitigation in the area, along with the identification and integration of a private inflow removal program in concert with the sewer separation program, and
- Final approval of the ADS revised flow metering data from Spring 2023 and then calibration of the combined sewer SWMM (using that data) to identify potential CSO reduction benefits that could be achieved by the Centralville area sewer separation program.
- Update of the Centralville PDR to add the additional information that will be collected over the next several months, discussion of the advantages and disadvantages of the two alternatives, selection of the preferred alternative, and updated project costs.

8.4 Implementation Schedule

Figure 8.1 shows a proposed schedule to complete the activities required to update this Centralville Sewer Separation PDR and to identify the final design scope of work.

The Utility is committed to meeting the CD Deadline for Phase I construction completion by December 31, 2027. It is expected that final design of the Phase 1 main conduit to remove Humphrey's Brook and Billings Street Wetlands will be completed by early January 2025, with a bid period in May 2025, and a construction contractor award by July 2025. The City will submit the State Revolving Fund (SRF) program application in October 2024 with design drawings and specifications.

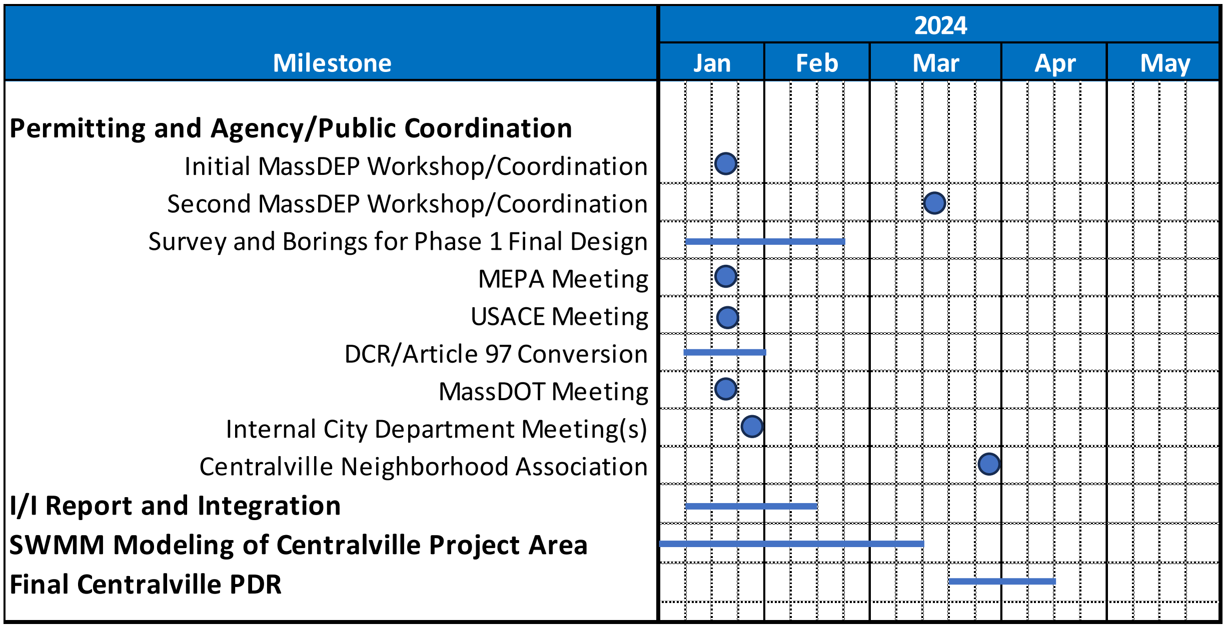


Figure 8.1 Implementation Schedule to Update the Centralville Preliminary Design Report